

ÉRITON EGIDIO LISBOA VALENTE

**SUPLEMENTAÇÃO DE BOVINOS DE CORTE EM PASTEJO COM
DIFERENTES RELAÇÕES PROTEÍNA: CARBOIDRATO DA FASE DE
AMAMENTAÇÃO AO ABATE**

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Zootecnia, para obtenção do título de *Doctor Scientiae*.

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BIOGRAFIA

Ériton Egidio Lisboa Valente, filho de Egidio Dimas Lisboa Valente e Mária de Fátima Bezerra Lisboa Valente, nasceu em Viçosa, Minas Gerais, no dia 28 de Outubro de 1984.

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RESUMO

VALENTE, Ériton Egidio Lisboa, D.Sc., Universidade Federal de Viçosa, Agosto de 2012. **Suplementação de bovinos de corte em pastejo com diferentes relações proteína: carboidrato da fase de amamentação ao abate.** Orientador: Mário Fonseca Paulino. Coorientadores: Edenio Detmann e Marcos Inácio Marcondes.

Foram elaborados 5 artigos científicos envolvendo a suplementação de bovinos de corte em pastejo com diferentes relações proteína: carboidrato. O artigo 1 objetivou-se avaliar o efeito da suplementação de bezerros sobre ganho de peso, consumo, digestibilidade, produção de leite de sua mães e comportamento ingestivo do par vaca-bezerro. Foram usados 55 vacas com peso médio inicial de 449 ± 8 kg e suas respectivas crias com peso inicial médio de 138 ± 3 kg. O período experimental foi de 112 dias. Os tratamentos foram: Controle = apenas mistura mineral; APAC = suplemento com alta proteína e alto carboidrato; APBC = suplemento com alta proteína e baixo carboidrato; BPAC = suplemento com baixa proteína e alto carboidrato; BPBC = suplemento com baixa proteína e baixo carboidrato. Cerca de 25 e 12,5% da exigência de proteína foram supridos nos suplementos com alta e baixa proteína, respectivamente, e cerca de 15 e 7,5% do requerimento de NDT foi suprido nos suplementos com alto e baixo carboidrato, respectivamente. A quantidade de suplemento múltiplo foi ajustada a cada 28 dias. O comportamento de pastejo, desempenho, produção e composição do leite, consumo e digestibilidade das vacas não foram influenciados ($P > 0,05$) pela suplementação dos bezerros. Os animais suplementados tiveram melhor desempenho ($P < 0,05$) (medida pelo peso corporal final, ganho médio diário (GMD), escore de condição corporal final), consumo e tempo ocioso, e menor tempo de pastejo ($P < 0,05$), mas a suplementação não afetou ($P > 0,05$) o tempo e a frequência de amamentação. Pode-se concluir que a suplementação afeta o comportamento e o consumo de alimentos pelos bezerros. Entretanto, não afeta o tempo e frequência de amamentação. No artigo 2 foram avaliados os efeitos da suplementação com diferentes relações de carboidrato e proteína sobre o desempenho de tourinhos dos 4 até 18. Foram usados os mesmos animais descritos no artigo 1. Os animais foram submetidos a um período experimental de 430 dias. Os tratamentos foram os mesmos descritos no artigo 1. Entretanto, após o desmame cerca de 50 e 25% da exigência de proteína foram supridos nos suplementos com alta e baixa proteína, respectivamente, e cerca de 30 e 15% do requerimento de NDT foi suprido nos suplementos com alto e baixo carboidrato, respectivamente. Os animais não suplementados apresentaram menor ($P < 0,05$) GMD do que os animais

suplementados. Os planos nutricionais com baixa oferta de carboidratos (APBC e BPBC) apresentaram maior eficiência de uso do suplemento. Pode-se concluir que a suplementação eleva o desempenho de tourinhos jovens. No entanto, os planos nutricionais que fornecem baixa quantidade de carboidratos apresentam maior eficiência de uso do suplemento. O artigo 3 avaliou o consumo e a digestibilidade de tourinhos jovens em pastejo suplementados com diferentes relações de carboidrato e proteína dos 4 aos 18 meses. A metodologia foi similar ao artigo 2. Em todos os grupos o consumo de MS foi maior ($P < 0,05$) na transição seca-águas e águas. Os animais não suplementados tiveram menores ($P < 0,05$) consumos de MS e de NDT em todas as fases, com exceção na época das águas. Apesar de não ter havido diferenças ($P > 0,05$) entre os animais suplementados quanto ao consumo de MS, os suplementos com alto carboidrato (APAC e BPAC) tiveram menor consumo de pasto ($P < 0,05$) nas fases de amamentação e águas. Entretanto, o grupo APAC apresentou o maior ($P < 0,05$) consumo e digestibilidade da FDN. Pode-se concluir que o consumo de MS são maiores na época de crescimento das plantas. Entretanto, o efeito do tipo de suplementação sobre os parâmetros nutricionais de animais em pasto tropical sofrem interação da época do ano. Suplementos com alto nível de proteína elevam o consumo e utilização da dieta, sendo o efeito mais intenso quando associado com alto nível de carboidrato. O artigo 4 comparou o tempo de pastejo por observação visual e por método eletrônico e avaliou os efeitos do plano nutricional sobre o comportamento de pastejo e locomoção horizontal e vertical de tourinhos em pastagem tropical. Foram usados 39 tourinhos Nelore com peso médio de $345 \pm 9,3$ kg. Os tratamentos foram os mesmos descritos no artigo 2, com adição de um grupo de animais com oferta de forragem restrita. Os animais foram equipados com colares GPS com sensores de atividades. Não foram encontradas diferenças ($P > 0,05$) no tempo de pastejo obtidos por observação visual ou método sensor de atividade. O grupo Restrito teve maior tempo de pastejo ($P < 0,05$) (9,58 horas/dia), mas não foram encontradas diferenças ($P > 0,05$) no tempo de pastejo entre o Controle (8,35 horas/dia) e animais suplementados (8,03 horas/dia). O grupo Restrito apresentou menor ($P < 0,05$) distância locomoção horizontal (2168 m/dia) em comparação com outros grupos (2580,6 m/dia). Pode-se concluir que a observação visual e método eletrônico apresentam resultados semelhantes. Além disso, a suplementação moderada não altera o comportamento de pastejo. O artigo 5 estimou as exigências nutricionais para manutenção de energia e para ganho de peso de energia e proteína de bovinos de corte em pastagens tropicais. Foram usados 44 bezerros de corte com peso inicial médio de 138.3 ± 3.4 kg e idade inicial entre 90 e 150 dias. Os

tratamentos foram os mesmos descritos no artigo 2. A exigência de energia líquida para ganho (EL_g) foi obtida pela regressão linear do logaritmo da energia retida em função do logaritmo do ganho de peso de corpo vazio. As exigências de energia líquida para manutenção (EL_m) foram estimadas a partir da relação exponencial da produção de calor (PC , kcal/PCVZ^{0,75}/dia) e o consumo de energia metabolizável. As exigências de proteína líquida para ganho (PL_g) foram obtidas pela regressão linear múltipla da proteína retida no peso de corpo vazio ($GPCVZ$, g/dia) e da energia retida (ER , kg/dia). A eficiência de uso da energia metabolizável (EM) para manutenção (k_m) foi 0.55, e para ganho (k_g) foi 0.26. O requerimento de EM para manutenção foi 124 kcal/kg PCVZ^{0.75}, 11% maior que a exigência de bovinos de corte confinados no Brasil. A exigência de PL_g reduziu com aumento do peso corporal. As exigências de energia líquida e proteína líquida para ganho podem ser obtidas pelas equações: ER (Mcal/kg) = $0,044 \times PCVZ^{0,75} \times GPCVZ^{1,1302}$, PR (g/dia) = $-31.45 + 229.69 \times GPCVZ - 8.75 \times ER$, respectivamente.

ABSTRACT

VALENTE, Ériton Egidio Lisboa, D.Sc., Universidade Federal de Viçosa, August, 2012. **Supplementation of grazing beef cattle with different relations protein: carbohydrate from suckling phase until slaughter.** Adviser: Mário Fonseca Paulino. Co-advisers: Edenio Detmann and Marcos Inácio Marcondes.

It was elaborated 5 articles relate with supplementation of grazing beef cattle with different relation protein: carbohydrate. The aim of article 1 was evaluate the effects of supplementation of beef calves on weight gain, intake and digestibility of pasture, milk production and composition of their dams and behavior of the pair cow-calf. Fifty-five beef cows (449 ± 8 kg) and their respective offspring, (138 ± 3 kg and 90-150 days) were used. Animals were submitted to an experimental period of 112-days. The experimental treatments consisted of: Control= mineral mixture only; HPHC= high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement. About 25% and 12.5% of the protein requirements were supplied by the high and low protein supplements respectively, and 15% and 7.5% of total digestible nutrients (TDN) requirements by the high and low carbohydrate supplements respectively. Grazing behavior, performance, milk production, milk composition, intake and digestibility of the cows were not affected ($P>0.05$) by the supplementation of the calves. The supplemented calves had greater ($P<0.05$) performance (as measured by final body weight, average daily gain and final body condition score), intake and idle time, and lower ($P<0.05$) grazing time, but supplementation did not affect ($P>0.05$) suckling time and suckling frequency. It can be concluded in the article 1 that supplementation affects the behavior and feed intake of calves. However, it does not affect the suckling time and suckling frequency of calves. Additionally, performance, milk production, nutritional characteristics and behavior of their dams are not affected. In the article 2, the objective was evaluate the effects of supplementation with different relations of carbohydrate and protein on performance of young bull from 4 until 18 months were assessed. Fifty-five beef calves with average initial body weight of 138.3 ± 3.4 kg and age between 90 and 150 days were used. Animals were submitted to a 430-days experimental period. The experimental treatments consisted of: Control= mineral mixture only; HPHC= high protein and high carbohydrate supplement; HPLC= high protein and low carbohydrate supplement; LPHC= low protein and high carbohydrate supplement; LPLC= low protein and low

carbohydrate supplement. The amount of supplement was adjusted every 28 days. The non-supplemented animals presented lower ($P<0.05$) average daily gain (ADG) than supplemented animals. Non-supplemented animals presented lower ($P<0.05$) DM intake than supplemented animals in the dry season. However, in the rainy period, differences were not observed ($P>0.05$) in DM intake. Nutritional plans with low supply of carbohydrate (HPLC and LPLC) presented greater supplement use efficiency. It can be concluded in the article 2 that supplementation increase performance of young bulls belong the productive cycle. However, nutritional plans that supply low amount of carbohydrate (until 15% of TDN requirement) have greater efficiency of supplement use. The article 3 aimed evaluate the intake and digestibility of young bulls supplemented with different ratios of protein: carbohydrates in tropical pastures from 4 until 18 months. The methodology was the same of the article 2. Dry matter (DM) intake was higher ($P<0.05$) in dry to rain transition and rain seasons for all nutritional plans. Non-supplemented calves had lower ($P<0.05$) intake of DM and total digestible nutrients (TDN) than supplemented calves in all seasons with exception in rain season. Although differences on DM intake was not observed ($P>0.05$) between supplemented animals, the supplements with high carbohydrate (HPHC and LPHC) had lower ($P<0.05$) forage intake ($P<0.05$) in the suckling phase (rain to dry transition season) and in the rain season. However, the HPHC plan had higher ($P<0.05$) intake and digestibility of neutral detergent fiber. It can be concluded in the article 3 that the effects of supplementation type on nutrition characteristics suffer interaction with season. Supplement with high protein level (supplying 50% CP requirement) increase intake and digestibility of diet, being more intense when associate with high carbohydrate level (supplying 30% TDN requirement). On other hand, supplement with low protein level (supplying 25% CP requirement) and high carbohydrate level decrease DM intake and fiber digestibility, occurring more intense in rainy season. The objective of the article 4 was to compare visual observation and an electronic grazing time method and to evaluate the effects of nutritional plans in intake, grazing behavior and horizontal and vertical locomotion of young bulls in a tropical pasture. Thirty-nine Nellore young bulls with an average body weight of 345 ± 9.3 kg were used. The experimental treatments consisted of: restricted: animals housed in a plot with a low mass of forage receiving mineral mixture only; and nutritional plans described in the article 2. GPS Collars equipped with activity sensors were used. Information about head position, latitude, longitude and altitude were recorded. Daytime grazing behavioral patterns monitored by a continuous focal animal recording method was compared to behavior estimated by the

activity sensor. Feed intake was measured by a marker method. The Restricted group presented lower ($P < 0.05$) intake of dry matter and TDN. However, differences were not found ($P > 0.05$) between non-supplemented and supplemented animals. Differences were not found ($P > 0.05$) in daytime grazing time obtained by visual observation or the activity sensor method. The restricted group showed longer ($P < 0.05$) grazing times (9.58 hours/day), but differences were not found ($P > 0.05$) in the grazing times between Control (8.35 hours/day) and supplemented animals (8.03 hours/day). The Restricted group presented lower ($P < 0.05$) horizontal locomotion distance (2168 m/day) in comparison to other groups (2580.6 m/day). It can be concluded in article 4 that the use of activity sensor methods is recommended due to being able to record 24-hours. While supplements with high carbohydrates reduce pasture intake, they have not changed grazing behavior. Moderate supplementation (until 50% of protein requirement and 30% of energy requirement) of beef cattle on tropical pasture has not effect on daily locomotion. The aim of the article 5 was estimate protein and energy requirement of beef cattle on tropical pastures from 4 until 18 months. Forty-six beef calves (138.3 ± 3.4 kg of BW and 90-150 days of age) housed in signal grass pasture were used. The treatments were the same of described in the article 4. The net energy requirement for weight gain (NEg) was obtained by linear regression of logarithm of retained energy in function of logarithm of empty body weight gain. The net energy requirement for maintenance (NEm) was estimated by exponential relation between heat production (kcal/EBW^{0.75}/day) and metabolizable energy intake. The net protein requirement for weight gain (RP) was estimated by multiple linear regression of retained protein in the weight gain of empty body and retained energy. The efficiency of metabolizable energy (ME) for maintenance (km) was 0.55 and for weight gain was 0.26. The ME requirement for maintenance was 124 kcal/EBW^{0.75}/day, 11% higher than the requirement for feedlot cattle in Brazil. The RP decreased with increase of body weight. The NEg and RP may be obtained by equations: $RE \text{ (Mcal/kg)} = 0.044 \times EBW^{0.75} \times EBWG^{1.1302}$, $RP \text{ (g/day)} = -31.45 + 229.69 \times EBWG - 8.75 \times RE$, respectively.

INTRODUÇÃO GERAL

Os fatores ambientais predominantes nos trópicos que promovem o crescimento vegetal (produção) também aceleram a maturação da planta e ampliam a participação de componentes estruturais na massa forrageira produzida, uma vez que favorecem a partição do *pool* metabólico nas plantas para a síntese de componentes de parede celular, em geral representados analiticamente pela fibra em detergente neutro (FDN) (Paulino et al., 2008). Nos trópicos, a principal fonte de energia para bovinos em pastejo é a fibra insolúvel, e deve-se procurar estratégias que maximizem seu uso, elevando o consumo e a taxa de passagem e melhorando a digestibilidade.

As condições de produção de bovinos no Brasil, as quais apresentam grande uso de pastos tropicais, permitem o fornecimento de substratos de baixo custo para os animais e fazem com que os custos de produção da carne brasileira seja de 80 a 90% inferiores aos custos da Austrália e dos Estados Unidos (ABIEC, 2007), principais concorrentes internacionais do Brasil.

Embora o Brasil apresente grandes vantagens competitivas na produção de carne bovina, pressões sobre o uso da terra ocupada por pastagens, em regiões tradicionalmente produtoras, são crescentes devido a diversos fatores, destacando-se a expansão do cultivo da cana-de-açúcar, das culturas florestais e da produção de grãos. Pode-se destacar ainda a intensificação das políticas públicas e dos movimentos de conservação ambiental que limitam o uso de determinadas áreas e a abertura de novos locais para produção.

Diante disto, faz-se necessário o uso de tecnologias que permitam a utilização mais eficiente do pasto, propiciando índices produtivos mais elevados, sendo a mais promissora, a suplementação múltipla em todas as épocas do ano (Paulino et al., 2001), respeitando-se as peculiaridades de cada época

A nutrição é, sem dúvida, o parâmetro de manejo que mais altera a idade do animal ao abate, ou seja, a precocidade ou a taxa com que o animal se aproxima do seu peso adulto é muito sensível às alterações do ambiente nutricional (Paulino et al., 2004).

Com a crescente demanda de produtos de origem animal faz-se necessária a maximização da produção animal a pasto. Desta forma, para um programa de produção contínua de carne que pretende ser eficiente e competitivo, torna-se essencial minimizar ou mesmo eliminar os efeitos da sazonalidade no desenvolvimento animal, proporcionando aos mesmos, condições para se desenvolver normalmente, durante todo o ano, a fim de que se alcancem as condições de abate mais precocemente.

Para propiciar crescimento contínuo de animais sob pastejo, visualiza-se a necessidade de suplementações estratégicas durante as diferentes épocas do ano, suprimindo os nutrientes limitantes e aumentando a eficiência de utilização das pastagens. Um desafio constante é prever com eficiência o impacto que a suplementação terá no desempenho animal. Uma estratégia de suplementação adequada seria aquela destinada a maximizar o consumo e a digestibilidade da forragem disponível. Este objetivo pode ser atingido através do fornecimento de todos, ou de alguns nutrientes específicos, os quais permitirão ao animal consumir maior quantidade de matéria seca disponível e digerir ou metabolizar a forragem ingerida de maneira mais eficiente (Hodgson, 1990).

A maioria dos trabalhos realizados sobre a suplementação de bovinos a pasto geralmente avaliam períodos específicos do ano ou determinadas fases do ciclo produtivo de forma isolada. A falta de informações sobre as bases nutricionais envolvidas na resposta à suplementação a pasto tem limitado a aplicação destes resultados nos sistemas comerciais de produção. Somente o conhecimento integrado das condições dos pastos que normalmente são influenciadas pela época do ano, do suplemento fornecido que pode variar em quantidade e composição, da capacidade de digestão do animal, muito dependente da relação entre pasto e suplemento, e das

exigências nutricionais do animal que variam com a fase de vida e a composição do ganho de peso dos animais, permitem gerar conhecimentos extrapoláveis para situações além daquelas onde o mesmo foi produzido.

Além disso, durante o ato de pastejo ocorrem modificações na massa e na oferta de forragem disponível, o que afeta o comportamento ingestivo e o desempenho dos animais, necessitando-se de estratégias de suplementação específica para cada situação específica.

A suplementação múltipla ao longo do ano, além de poder aumentar o ganho de peso individual de animais em pastejo, eleva a produção por área (Fernandes et al., 2010), elevando a produtividade do sistema.

O sistema de produção em pastejo é marcado pelas suas características multifatoriais e interativas que afetam além do consumo e utilização dos alimentos, a exigência nutricional dos animais. Os principais fatores que afetam a demanda nutricional são a quantidade e qualidade de forragem (Aharoni et al. 2004), taxa de lotação (Brosh et al. 2006), suplementação (Scaglia et al. 2009), tamanho do piquete (Hunt et al. 2007), inclinação do terreno (Brosh et al. 2010) e o clima (Brosh et al. 2006). O CSIRO (2007) cita que em condições desfavoráveis de produção o requerimento energético de manutenção de animais em pastagens pode elevar-se em até 50%.

O sistema de produção de bovinos de corte em pastagens é responsável pela grande maioria dos animais abatidos no Brasil. Entretanto, a maioria dos trabalhos para estimar as exigências nutricionais dos bovinos é realizada em condições de confinamento. Contudo, nos últimos anos tem sido desenvolvido trabalhos avaliando as exigências nutricionais em condições de pastejo (Porto et al. 2012), embora, devido à complexidade e ao número de fatores relacionados a resposta animal, aliado a escassez de trabalhos de longa duração e que envolvam as fases iniciais de produção, mais

estudos precisam ser desenvolvidos para melhorar as informações dos requerimentos nutricionais nestas condições de produção.

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Effect of calves supplementation on performance, nutritional and behavioral characteristics of their dams¹

¹ Tropical Animal Health and Production

Abstract The effects of supplementation of beef calves on weight gain, intake and digestibility of pasture, milk production and composition of their dams and behavior of the pair cow-calf were assessed. Fifty-five beef cows with an initial average-body weight of 449 ± 8 kg and their respective offspring, with an initial average body weight of 138 ± 3 kg and aged between 90 and 150 days, were used. Animals were submitted to an experimental period of 112-days. The experimental treatments consisted of: Control= mineral mixture only; HPHC= high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement. About 25% and 12.5% of the protein requirements were supplied by the high and low protein supplements respectively, and 15% and 7.5% of total digestible nutrients (TDN) requirements by the high and low carbohydrate supplements respectively. Grazing behavior, performance, milk production, milk composition, intake and digestibility of the cows were not affected ($P>0.05$) by the supplementation of the calves. The supplemented calves had greater ($P<0.05$) performance (as measured by final body weight, average daily gain and final body condition score), intake and idle time, and lower ($P<0.05$) grazing time, but supplementation did not affect ($P>0.05$) suckling time and suckling frequency. It can be concluded that supplementation affects the behavior and feed intake of calves. However, it does not affect the suckling time and suckling frequency of calves. Additionally, performance, milk production, nutritional characteristics and behavior of their dams are not affected.

Keywords cattle, creep feeding, digestibility, grazing, intake, Nellore

Introduction

The production system of grazing beef calves is composed of the cow-calf pair. Thus, it is important to understand the interaction between cows and their calves in production conditions, as the occurrence of any change in a component, may affect the response in one another.

Milk is the main energy and nutrient source for young calves. However, as they grow older, their requirement increases and milk intakes decreases. In beef cattle, milk is not sufficient to supply the calves requirements when they are about 3 months of age (Henriques et al. 2011). This shortage of milk usually occurs in Brazilian tropical regions during the transition between the rainy and dry seasons, a period when there is a reduction in the availability and quality of forage. As a consequence calves cannot reach their genetic potential for performance. Thus, performance improvements occur when grains are supplemented (Valente et al. 2012), especially with protein supplement (Valente et al. 2011).

Supplement intake may influence calf behavior, affecting the total suckling duration and also the daily suckling frequency. Similarly it may also be influenced by the milk production of its dam (Odde et al. 1985)

On the other hand, milk production may be increased as the calf stimulates the mammary gland (Vargas Junior et al. 2011). Therefore, factors that affect milk secretion, such as calf supplementation, may affect the energy and nutrient requirements of the dam. As a consequence, this may affect feed intake and performance of the cows.

Thus, the objective of this study was to evaluate the effects of beef calves supplementation on the weight gain and intake of calves and cows, the digestibility of pasture, the milk production and composition of the cows and the behavior of the cow-calf pair.

Materials and methods

Animals, experiment design and diets

All procedures involving animals were approved by the Brazilian Committee for Animal Care and Experimentation.

This experiment was conducted at the Beef Cattle Sector at the Federal University of Viçosa, in Viçosa, MG, Brazil (20°45' S, 42°52' W). The experimental area is located in a hilly region at an altitude of 670m, with an average rainfall of 1300 mm.

This study was carried out during the transition phase between the rainy and dry seasons, from March to June, 2010. The minimum and maximum temperatures during the experiment were 19 and 29 °C in March, 16 and 27 °C in April, 14 and 25 °C in May, and 10 and 24 °C in June, respectively. The rainfall was 192 mm in March, 18 mm in April, 46 mm in May and 1 mm in June.

Fifty-five beef cows (30 Nellore; 10 ½ Nellore ½ Holstein; 15 ¾ Nellore ¼ Holstein) were used in this experiment with initial average body weight of 449 ± 8 kg and body condition score of 4.3 ± 0.1 (scale ranging from 1 to 9), and their respective calves with an initial average body weight of 138 ± 3 kg and aged between 90 and 150 days. Only Nellore sires were used in this study.

Animals were submitted to a 14-day adaptation period and to a further period of 112 days for the evaluation of performance and behavior. These animals were allocated into five groups. Each group was placed in a 10-ha paddocks with *Urochloa decumbens* pastures. Drinkers and feeders in each plot were shaded with asbestos tiles. There were private feeders for the calves (0.5m per calf). The cow-calf pair was randomly assigned to one of the five following experimental treatments: Control= mineral mixture only; HPHC= high protein and high carbohydrate multiple supplement; HPLC = high protein

and low carbohydrate multiple supplement; LPHC = low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement (Table 1). Approximately 25% and 12.5% of protein requirement was supplied by the high and low protein supplements, respectively. About 15 and 7.5 % of total digestible nutrients (TDN) requirements was supplied by the high and low carbohydrate supplements, respectively. The amount of multiple supplements was adjusted every 28 days by using the protein and energy requirements estimated by BR-CORTE (Valadares et al. 2006).

Calves were fed once a day at 11 a.m. Cows received a mineral mixture *ad libitum* and 100 g of corn meal per day, in feeders located parallel to the creep-feedings in order to allow calves to spend more time in the feeder for supplement consumption. Diet compositions are presented in Table 2.

In order to minimize the possible effects of plots on the experimental treatments, animals were rotated among the four pastures every 7 days, so each group stayed for the same period of time in each plot.

Body condition score (BCS) of the cows was recorded using a scale of 1 to 9 as recommended by NRC (1996); all evaluations were made by the same four trained evaluators. Variation of BCS was determined by the difference between scores recorded at the beginning and at the end of the experimental period.

Diurnal behavior of cows and calves was monitored by human observation. Binoculars were used for this observation and the observers stayed at a minimum distance of 50 m, from 6 a.m. to 6 p.m. on days 30, 60 and 90 of the experimental period, through the continuous focal animal recording method. Behaviors observed in this work were, the time the animals spent grazing, idling, ruminating, suckling and the number of suckles.

Experimental procedures and sampling

Forage samples were randomly taken every 28 days for the evaluation of forage mass. In each plot, six forage samples were randomly selected using a metal square (0.5 x 0.5 m) and cut at approximately 1 cm above the ground. After that, forage subsamples (200 g) were dried at 60 °C for 72 h and then ground to pass through a 1-mm screen sieve.

Every 7 days, manual simulation of grazing was performed simultaneously to observe the grazing behavior of the animals in order to obtain samples to evaluate the chemical composition of the forage, consumed by the animals. All samples were dried at 60 °C for 72 hours and then ground to pass through a 1-mm screen. Samples were then proportionally sub-sampled into a composite sample for each period.

In order to evaluate the forage intake and digestibility of the cows and calves, a digestion trial was performed simultaneously to evaluate the animals' performance from day 48 and day 56 of the experimental period. Fecal dry matter excretion was determined by using chromic oxide (Cr_2O_3) as an external marker, 20g/day for cows and 10g/day for calves. This material was packaged in a paper cartridge and directly introduced into the esophagus by using a rubber tube. The animals received the marker once a day at 11 a.m., for 7 days during the digestion trial. To estimate the individual intake of mineral mixture in cows and calves, the Control animals received mineral mixture with 15% of titanium dioxide, *ad libitum*. After 5 days of adaptation during the digestion trial period, fecal samples were collected at 3 p.m. on day 6, at 11 a.m. on day 7, and at 7 a.m. on day 8. The fecal samples were dried at 60°C for 72 h, then ground to pass through a 1-mm screen, and proportionally sub-sampled into a composite sample. On day 5 of the digestion trial, a manual grazing simulation was performed in each experimental plot and a sample was taken to estimate dry matter intake and pasture digestibility.

To evaluate microbial protein production of cows, spot urine samples (10 mL) were collected from spontaneous urination, 4 hours after supplement intake. Urine samples were diluted in 40 mL of H₂SO₄ (0.036 N) and frozen at -20 °C.

To estimate the milk production of the cows, milk samples were obtained on days 28, 57 and 84 of the experimental period. Cows were separated from their calves at 6 p.m. At 6 a.m. the following day, cows were milked immediately after an injection of 2 mL of oxytocin (10 IU/mL; Ocitovet®, Brazil) in the mammary vein and the produced milk was weighed within 2 h from start to finish of milking. The exact time when each cow was milked was recorded, and the milk produced was converted into a 24-h production. The milk produced was corrected to 4% of fat (4% fat-milk) calculated by the following equation:

$$4\% \text{ fat-milk (kg)} = 0.4 \times (\text{milk production}) + [15 \times (\text{fat production} \times \text{milk production}/100)]$$

Chemical analysis

Forage, feces, supplements and ingredient samples were analyzed for dry matter (DM), nitrogen compounds (N), ash and ether extract (EE) according to AOAC (Association of Official Analytical Chemists-AOAC 1990). Lignin content was obtained by cellulose solubilized with sulfuric acid (Van Soest and Robertson 1985). For analysis of neutral detergent fiber (aNDF), samples were treated with alpha thermostable amylase without sodium sulfite and corrected for ash residue (Mertens 2002) and residual nitrogen compounds (Licitra et al. 1996). Indigestible neutral detergent fiber (iNDF) was analyzed as described by Casali et al. (2008). Fecal samples were evaluated for chromium and titanium dioxide content by using atomic absorption (Willians et al. 1962) and colorimetric (Myers et al., 2004) methods, respectively.

Content of non-fibrous carbohydrate, corrected for ash and protein (NFCap), was calculated by using the following equation: $NFC = 100 - [(\%CP - \%CP \text{ urea} + \% \text{ of urea}) + \% \text{aNDF} + \%EE + \%ash]$ (Detmann & Valadares Filho 2010). Mass of forage samples obtained was analyzed for DM, as previously described.

Milk was analyzed for protein, fat, lactose and total solids content, using spectroscopy (Foss MilkoScan FT120, Hillerød, Denmark). The calcium and phosphorus content in milk were analyzed according to AOAC (Association of Official Analytical Chemists-AOAC 1990).

The fecal excretion was estimated by ration of quantity offered of chromic oxide and the concentration in feces.

The voluntary dry matter intake (DMI) was estimated by using the NDFi as an internal marker and calculated by the following equation:

$$DMI \text{ (kg/day)} = [(FE \times iNDF \text{ feces}) - iNDF \text{ supplement}] \div NDFi \text{ forage} + SI + MI,$$

Where FE is the fecal excretion (kg/day); iNDF feces is the concentration of NDFi in the feces (kg/kg); iNDF supplement is the iNDF in the supplement (kg), iNDF forage is the concentration of iNDF in forage (kg/kg), SI is the supplement intake and, MI is the milk intake.

The estimation of the individual intake of mineral mixture was obtained by using the external marker titanium oxide by using the following equation:

$$DMSI = (FE \times MCF) / MCS$$

Where DMSI is the dry matter supplement intake (kg/day); FE is the fecal excretion (kg/day); MCF is the marker concentration in the animal feces (kg/kg); MCS is the marker concentration in the supplement (kg/kg).

Analyses of creatinine, uric acid and allantoin in urine and microbial protein estimates were performed similarly to the description of Valente et al. (2011).

Efficiency of protein microbial synthesis was determined by dividing protein microbial production by the TDN intake.

Statistical analysis

This study was conducted under a completely randomized design using a 2 x 2 + 1 factorial arrangement (two protein levels, two carbohydrate levels and one control). The calves' initial BW and cow's BW and BCS were used as covariate for the data analysis.

The data were analyzed using the GLM procedure of SAS version 9.1, (SAS Institute, Inc).

Results

Average forage mass production over the experimental period was 3.8 ton/ha. The forage sampled by a manual grazing simulation was considered as low quality forage, presenting 8.7 % CP (Table 2) which is lower than the level of CP (9%) suggested by Figueiras et al. (2010), which would optimize forage use by grazing cattle.

The average supplement intake was 0.035, 0.716, 0.347, 0.712 and 0.354 kg/animal/day for Control, HPHC, HPLC, LPHC and LPLC, respectively. Supplement use efficiency (additional weight gain of supplemented calves/supplement intake) was 0.282, 0.481, 0.300 and 0.570 for HPHC, HPLC, LPHC and LPLC, respectively.

Calves supplementation did not affect ($P>0.05$) the grazing, ruminating and idle time of their dams. On the other hand, grazing time decreased and the idle time of the calves, increased with supplementation ($P<0.05$). Moreover, there was interaction ($P<0.05$) between protein and carbohydrate on grazing time. The high level of carbohydrate (HPHC and LPHC) resulted in a greater ($P<0.05$) idle time than the low level of carbohydrate (HPLC and LPLC). However, supplementation did not affect ($P>0.05$) suckling time and suckling frequency (Table 3).

The supplementation of calves did not affect ($P>0.05$) final body weight (FBW), average daily gain (ADG) and final body condition score (FBCS). However, supplemented calves performed better ($P<0.05$) than calves which only received mineral mixture (Table 4).

Intake, digestibility and microbial synthesis of the cows were not affected ($P>0.05$) by the supplementation of the calves (Table 5 and 6). Similarly, milk production and milk composition was not affected ($P>0.05$) by the supplementation of the calves (Table 7).

Discussion

Standing Forage and Forage Quality

Forage intake is determined by both nutritional and the non-nutritional factors. The nutritional factors are related to the nutritional value of forage and metabolic factors; the non-nutritional factors are associated with intake behavior (Carloto et al. 2011). Forage mass and canopy structure may limit roughage intake by cattle on pasture (Palhano et al. 2007). Thus, intake is determined by metabolic requirement (the capacity of supply nutrients by feed), filling capacity of the digestive tract and the effect of time spent on intake activities.

Apparently, forage mass did not limit feed intake. Nonetheless, forage was low quality forage, limiting forage use (Figueiras et al. 2010). Therefore, pasture intake may be limited by the insufficient supply of nutrients to the rumen. This may reduce the intensity and speed of pasture degradation. Thus, the intake of digestible dry matter was low by protein limitation.

Behavior

In grazing cattle, most feeding occurs in daylight. Scaglia et al. (2009) observed that 70% of grazing time occurred during daylight. Therefore, factors that determine grazing time become more evident in daylight. Thus, the evaluation of grazing behavior in daylight may present a similar trend to a 24-hour evaluation.

Grazing time may be determined by many factors, such as those related to quality (Vargas Junior et al. 2010), the amount of pasture (Scaglia et al. 2009), and the metabolism of the animal (Brosh et al. 2006). However, these factors are interrelated. For example, when canopy structure is inadequate, cattle spend more time grazing and less time idling to try to supply the demand for nutrients. Moreover, milk production increases nutritional requirements and subsequently may determine grazing time.

Milk production of cows is reduced as lactation advances. Thus, the energy requirements of the cow decrease and consequently there is a reduction in intake and grazing time, and an increase in idle time. On the other hand, calves need to increase solid feed intake to compensate the reduction in milk intake, which may increase grazing time and decrease idle time. Rumination time is proportional to rough feed intake, which in turn, is proportional to grazing time and forage quality.

According to Kress et al. (1990), suckling frequency determines milk production and body conditions of the dams, so that a high frequency of suckling may increase milk production and reduce the body conditions of cows. Nonetheless, in the present study, milk production was not affected ($P>0.05$) by the supplementation of the calves, which is in agreement with the results reported by Valente et al. (2012). However, according to Fordyce et al. (1996), the supplementation of calves may reduce milk production of cows due to a reduction in suckling stimulation. In addition, solid intake by a calf is negatively correlated to milk yield (Henriques et al. 2011). Therefore, it seems that the supplement used in the present study was not sufficient to change the

suckling behavior of the calves (Table 3) and consequently did not affect ($P>0.05$) cow milk production, BCS and BW (Table 4).

Supplementation did not affect the frequency and duration of suckling. Therefore, there were no differences in stimulation intensity to milk secretion among treatments. Thus, effects of supplement and non-supplement calves on cows were similar, consequently, milk production and the nutritional requirements of cows did not change with the nutritional plan of their offspring.

Non-supplemented calves were more dependent on pasture to supply their diets than supplemented calves, spending more time ($P<0.05$) grazing. Supplement intake reduces grazing time, but it is dependent on the amount of intake (Scaglia et al. 2009). Although differences in grazing time were not observed, calves with a greater intake of multiple supplements (HPHC and LPHC) presented a longer idle time.

There was an interaction between levels of protein and carbohydrate in grazing time. Calves that received high carbohydrate and low protein (LPHC, supplement with 15.4% CP) spent less time grazing. This probably occurred because energy supplements reduce fiber utilization (Souza et al. 2010) and consequently, pasture utilization. Thus, a reduction in grazing time may occur.

Multiple supplements improve rumen conditions and increase energy intake by increasing pasture utilization and/or direct energy supply (NFC). Calves that received a high level of carbohydrate (HPHC and LPHC) had longer idle times than calves that received a low level of carbohydrate (HPLC and LPLC). This probably occurred because calves which were fed a high level of carbohydrate had a greater proportion of energy from supplement and spent a shorter time consuming and processing pasture, than calves that received low level of carbohydrate.

Weight gain and corporal condition

Milk production and the performance of beef calves are strongly correlated ($r=0.80$) (MacNeil et al. 2006). However, in this work, the performance of calves increased with supplementation. Thus, milk intake and tropical grazing pasture were not enough to supply the nutritional demand of calves.

The greater performance of supplemented calves, observed in this study, may be the result of increasing total intake and digestibility caused by multiple supplement intake (Porto et al. 2009, Sampaio et al. 2010). Strategies such as creep-feeding, which allows calves access to concentrate feeds at an early stage, have been successfully used to progressively reduce its nutritional and social dependence on the cow (Enríquez et al. 2011). Thus, the supplementation of calves may increase weight gain during the suckling period, reducing the weaning stress and consequently improving pos-weaning performance. One of the main reasons for the improvement in performance might be better rumen conditions at an early stage of development which allows better grazing efficiency.

Differences in performance and body condition of cows as a consequence of the calves' nutritional plan were not observed ($P>0.05$) in this study because the treatment of calves did not affect milk production. Consequently, there were no differences in energy and nutrient requirements of cows among nutritional plans. Thus, intake, behavior and the performance of cows were similar among treatments. However, Sampaio et al. (2010) observed low body reserves in cows whose offspring received supplement.

Milk production, Feed intake and digestibility

Average milk production was 6.2 kg/day, which is greater than 5.0 and 5.4 g/day of milk reported by Oliveira et al. (2007) and Valente et al. (2012), respectively, who observed milk production of Nellore cows. The Holstein crossbred cows observed in

this work have a greater genetic potential for milk production than purebred Nellore cows.

Henriques et al. (2011) observed a negative correlation between the feed intake of the calf and the milk production of its dam. However, because of the complexity of intake control, many factors should be regarded for the determination of intake. Although supplemented calves had greater ($P < 0.05$) DM intake than non-supplemented calves, no differences were found in the time and frequency of suckling. This probably occurred because calves preferred milk to solid feed intake. Therefore, it is unlikely that calves substitute milk with solid feed. Thus, calves will usually increase pasture and supplement intake only after the maximization of milk intake.

The supplementation of calves for protein and carbohydrate requirements, allowed for the efficient use of supplement substrates. The nutritional requirements of calves are determined, mainly, by body weight and weight gain. Thus, in a situation, in which a basal diet (pasture) is limiting performance, the nutritional requirement and supplement offered will be lower than in a situation in which pasture presents greater quality. Therefore, the objective is not to maximize weight gain but to increase energy and nutrients available to animals with the efficient utilization of supplement.

The supplementation of calves for nutritional requirements, allowed a moderate use of supplement with greater efficiency. In production systems, in which the objective is to improve cattle performance with the efficient use of supplements, the control of the supplement level supplied for the potential performance of the pasture, may be an important production strategy.

The premise that feed intake is controlled only by physiological demand has drawn the conclusion that a reduction in milk production decreases the energy and nutrient requirements of the cow and consequently its feed intake. Moreover, grazing cows have additional energy demands for physical activities (Brosh et al. 2006, 2010)

and therefore, they have high nutritional demands and need to spend a long time grazing. However, Merrill et al. (2008) when studying grazing cows did not find differences in grazing time and feed intake with early weaning. Therefore, it is presumed that other factors are related to the feed intake of milking cows in pastures.

In addition to behavior and physiological effect, ruminal effects may determine feed intake. In low quality pastures, energy extraction is limited by nitrogen available to microbial enzyme synthesis (Lazzarini et al. 2009b; Sampaio et al. 2009; Detmann et al. 2009). Therefore, when pasture protein content is low, such as in this study, the ruminal limitation may determine the feed intake, even if metabolic demand is not entirely supplied.

Conclusions

The supplementation of grazing calves does not affect grazing behavior, performance, milk production, intake and digestibility of their dams. However, performance and feed intake are improved. Similarly, there is a reduction in grazing time and an increase in the idling time of calves. However, there were no changes in suckling time and frequency.

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Table 1 Composition of supplement.

	Nutritional Plans ¹				
	Control	HPHC	HPLC	LPHC	LPLC
		High protein		Low protein	
		High	Low	High	Low
carbohydrate		carbohydrate	carbohydrate	carbohydrate	
Corn	-	55	0	83.5	53
Corn gluten	-	3	20	0	14
Soybean meal	-	37	70	12	24
Urea/ A.S. ²	-	1	2	0.5	1
MM ³	100	4	8	4	8

¹ HPHC = high protein and high carbohydrate multiple supplement; HPLC = high protein and low carbohydrate multiple supplement; LPHC= low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement. ²Urea + ammonia sulfate (9:1). ³ Mineral mixture; composition: calcium: 8.7 %, phosphor: 9.0 %, sulfur: 9.0 %, sodium: 18.7 %, zinc: 2400.00 mg/kg, copper: 800.00 mg/kg, manganese: 1600.00 mg/kg, iodine: 40.00 mg/kg, cobalt: 8.00 mg/kg, selenium: 8,16 mg/kg. ⁶Neutral detergent fiber corrected for ash and protein. ⁷ Non-fiber carbohydrate.

Table 2 Chemical composition of supplement and forage.

	HPHC	HPLC	LPHC	LPLC	<i>U. decumbens</i> ¹
Dry matter	87.1	89.5	85.8	87.0	28.3
Organic matter	89.3	87.4	88.4	85.8	91.4
Crude protein	29.2	55.3	15.4	29.5	8.7
NDFap ²	14.9	14.7	14.5	14.0	73.7
Ether extract	2.6	1.5	3.0	2.4	1.2
NFCap ³	46.2	23.3	57.2	43.6	7.9

¹ Obtained by the hand plucking technique. ² Neutral detergent fiber corrected for ash and protein. ³ Non-fiber carbohydrate corrected for ash and protein.

Table 3 Diurnal behavior (%) of cows and calves.

	Nutritional Plans ¹					CV (%)	Contrasts ²			
	Control	HPHC	HPLC	LPHC	LPLC		CT	P	C	P*C
	Cows									
Grazing	63.9	63.5	63.7	64.8	65.4	8.0	ns	ns	ns	ns
Rumination	20.9	21.0	23.0	20.1	20.9	15.4	ns	ns	ns	ns
Idle	15.3	15.5	13.3	15.2	13.6	27.8	ns	ns	ns	ns
	Calves									
Grazing	49.9	46.6	45.5	44.0	47.0	8.9	*	ns	ns	*
Rumination	15.8	13.2	17.2	16.3	15.4	28.0	ns	ns	ns	ns
Idle	31.3	38.0	34.6	36.6	34.1	16.7	*	ns	*	ns
Suckling	22.0	18.8	22.0	21.0	21.0	28.1	ns	ns	ns	ns
Suckling frequency	2.6	2.2	2.4	2.4	2.4	24.8	ns	ns	ns	ns

¹ HPHC = high protein and high carbohydrate multiple supplement; HPLC = high protein and low carbohydrate multiple supplement; LPHC= low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement. ² CT= non-supplemented versus supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate. (ns), (*) = non-significant (P > 0.05) and significant (P<0.05), respectively.

Table 4 Least square means and coefficient of variation for final body weight (FBW, kg), average daily gain (ADG, kg/day) and final body condition score (FBCS) of suckling calves and their dams according to the supplementation of calves.

	Nutritional Plans ¹					CV (%)	Contrasts ²			
	Control	HPHC	HPLC	LPHC	LPLC		CT	P	C	P*C
	Cows									
FBW	461	476	469	466	462	4.0	ns	ns	ns	ns
ADG	0.085	0.219	0.159	0.132	0.094	125.0	ns	ns	ns	ns
FBCS	3.9	4.2	4.1	4.1	3.8	8.7	ns	ns	ns	ns
	Calves									
FBW	208	232	227	233	232	4.8	*	ns	ns	ns
ADG	0.608	0.810	0.775	0.822	0.810	12.3	*	ns	ns	ns

¹ HPHC = high protein and high carbohydrate multiple supplement; HPLC = high protein and low carbohydrate multiple supplement; LPHC= low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement. ² CT= non-supplemented versus supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate. (ns), (*) = non-significant (P > 0.05) and significant (P<0.05), respectively.

Table 5 Least square means and coefficient of variation for intake of dry matter (DM), organic matter (OM), neutral detergent fiber corrected for ash and protein (NDFap), crude protein (CP), ether extract (EE), non-fiber carbohydrate corrected for ash and protein (NFCap), total digestible nutrients (TDN) and indigestible neutral detergent fiber (iNDF), of beef cows and their offspring according to the supplementation of calves.

	Nutritional Plan ¹					CV (%)	Contrasts ²			
	Control	HPHC	HPLC	LPHC	LPLC		CT	P	C	P*C
	Cows									
	Kg/d									
DM	12.4	12.6	11.8	11.6	12.3	17.6	ns	ns	ns	ns
OM	11.6	11.7	10.9	10.6	11.3	17.6	ns	ns	ns	ns
NDFap	8.8	8.9	8.2	8.0	8.5	17.7	ns	ns	ns	ns
CP	1.1	1.1	1.0	1.0	1.1	15.4	ns	ns	ns	ns
EE	0.2	0.2	0.1	0.2	0.2	17.5	ns	ns	ns	ns
NFCap	1.6	1.5	1.6	1.5	1.4	19.8	ns	ns	ns	ns
TND	6.8	6.3	6.4	6.6	6.7	22.6	ns	ns	ns	ns
	g/Kg BW									
DM	28.3	27.3	24.5	27.0	26.3	16.2	ns	ns	ns	ns
NDFap	20.1	19.1	17.3	18.7	18.2	16.2	ns	ns	ns	ns
iNDF	6.8	6.7	6.3	7.1	6.8	15.9	ns	ns	ns	ns
	Calves									
	g/Kg BW									
Dry matter	13.4	17.6	15.0	17.0	15.7	28.0	*	ns	ns	ns

¹ HPHC = high protein and high carbohydrate multiple supplement; HPLC = high protein and low carbohydrate multiple supplement; LPHC= low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement. ² CT= non-supplemented versus supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate. (ns), (*) = non-significant ($P > 0.05$) and significant ($P < 0.05$), respectively.

Table 6 Least square means and coefficient of variation for digestibility of dry matter (DM), organic matter (OM), neutral detergent fiber corrected for ash and protein (NDFap), crude protein (CP), ether extract (EE), non-fiber carbohydrate corrected for ash and protein (NFCap) and total digestible nutrients (TDN), and microbial protein synthesis (MNS) and efficiency of microbial protein synthesis (EMPS, microbial CP synthesis/ TDN intake) of beef cows according to the supplementation of calves.

	Nutritional Plans ¹					CV (%)	Contrasts ²			
	Control	HPHC	HPLC	LPHC	LPLC		CT	P	C	P*C
	%									
DM	53.9	53.7	53.1	53.6	54.8	3.7	ns	ns	ns	ns
OM	57.6	9.0	58.1	57.9	58.9	3.1	ns	ns	ns	ns
NDFap	62.4	63.6	63.2	63.4	64.9	3.9	ns	ns	ns	ns
CP	52.6	47.9	54.9	56.4	53.3	26.0	ns	ns	ns	ns
EE	-37.9	-15.3	-14.8	-19.1	-9.7	80.5	ns	ns	ns	ns
NFCap	37.9	36.6	39.8	37.6	40.5	15.0	ns	ns	ns	ns
TDN	52.9	48.9	53.6	53.6	54.6	13.0	ns	ns	ns	ns
MPS	145.8	154.9	149.5	154.6	152.1	19.3	ns	ns	ns	ns
MEPS	135.8	149.8	145.8	144.3	136.8	16.4	ns	ns	ns	ns

¹ HPHC = high protein and high carbohydrate multiple supplement; HPLC = high protein and low carbohydrate multiple supplement; LPHC= low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement. ² CT= non-supplemented versus supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate. (ns) = non-significant (P > 0.05).

Table 7 Milk production and composition of beef cows according to the supplementation of calves.

	Nutritional Plans ¹					CV (%)	Contrasts ²			
	Control	HPHC	HPLC	LPHC	LPLC		CT	P	C	P*C
	Kg/d									
Milk	5.9	6.2	6.3	6.2	6.3	21.1	ns	ns	ns	ns
4% fat-milk ³	7.0	6.8	6.9	6.9	7.3	19.6	ns	ns	ns	ns
Protein	0.2	0.2	0.2	0.2	0.2	18.6	ns	ns	ns	ns
Fat	0.3	0.3	0.3	0.3	0.3	11.0	ns	ns	ns	ns
Lactose	0.3	0.3	0.3	0.3	0.3	19.5	ns	ns	ns	ns
Total solids	0.8	0.8	0.9	0.9	0.9	17.9	ns	ns	ns	ns
	g/Kg									
Protein	36.7	35.7	35.2	35.5	26.9	7.7	ns	ns	ns	ns
Fat	46.2	47.5	46.8	45.0	50.0	20.7	ns	ns	ns	ns
Lactose	43.9	43.4	45.5	45.3	44.6	3.9	ns	ns	ns	ns
Total solids	145.0	138.4	138.8	140.6	143.6	7.2	ns	ns	ns	ns
Calcium	17.6	18.7	18.1	18.6	17.3	9.9	ns	ns	ns	ns
Phosphor	4.6	4.5	4.4	4.6	4.3	10.7	ns	ns	ns	ns
	g/d									
Calcium	99.7	114.5	108.5	113.0	111.0	19.3	ns	ns	ns	ns
Phosphor	24.9	26.2	27.1	27.6	27.2	22.9	ns	ns	ns	ns

¹ HPHC = high protein and high carbohydrate multiple supplement; HPLC = high protein and low carbohydrate multiple supplement; LPHC= low protein and high carbohydrate multiple supplement; LPLC = low protein and low carbohydrate multiple supplement. ² CT= non-supplemented versus supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate. (ns) = non-significant (P > 0.05). ³ 4% fat-corrected milk yield.

Performance of young bulls receiving supplements with different ratio of protein to carbohydrate from suckling phase until fattening in tropical pasture¹

Abstract Effects of supplementation with different relations of carbohydrate and protein on performance of young bull from 4 until 18 months were assessed. Fifty-five beef calves with average initial body weight of 138.3 ± 3.4 kg and age between 90 and 150 days were used. Animals were submitted to a 430-days experimental period. The experimental treatments consisted of: Control= mineral mixture only; HPHC= high protein and high carbohydrate supplement; HPLC= high protein and low carbohydrate supplement; LPHC= low protein and high carbohydrate supplement; LPLC= low protein and low carbohydrate supplement. The amount of supplement was adjusted every 28 days. The non-supplemented animals presented lower ($P < 0.05$) average daily gain (ADG) than supplemented animals. Non-supplemented animals presented lower ($P < 0.05$) DM intake than supplemented animals in the dry season. However, in the rainy period, differences were not observed ($P > 0.05$) in DM intake. Nutritional plans with low supply of carbohydrate (HPLC and LPLC) presented greater supplement use efficiency. It can be concluded that supplementation increase performance of young bulls belong the productive cycle. However, nutritional plans that supply low amount of carbohydrate (until 15% of TDN requirement) have greater efficiency of supplement use.

Keywords associative effects, beef cattle, calf, grazing, multiple supplement, production

Introduction

In Brazil, as in most tropical regions, beef cattle production is realized majority in pasture conditions. However, tropical pasture does not usually present appropriate

nutritional balance to maximize weight gain. Thus, multiple supplementation increases the performance in dry season (Goes et al. 2010, Porto et al. 2011, Valente et al. 2011) as well as in rainy season (Acedo et al., 2011, Barros et al. 2011a, Barros et al. 2011b).

Most works on grazing cattle production involves a specific year period or a part of production cycle. Thus, it is not possible to create a holistic view on production system of supplemented grazing cattle. In this situation, it is not possible consider the residual effects of supplementation and the results may be conflicting with the ones found in commercial production system.

Strategic supplementation among seasons, supplying limiting nutrients and increasing efficiency of pasture use, is an important way to provide continuous growth of grazing cattle. The multiple supplementation throughout the year improves individual weight gain and production per area (Fernandes et al. 2010).

The performance of supplemented grazing cattle is a function of many factors such as pasture quality, supplementary nutrients and relationship between the substrates, specially between protein and energy. The supplementation of protein and carbohydrate jointly or separately determines the interaction effects on intake and digestibility (Souza et al. 2011). However, the intensity of these effects is determined by composition of the basal diet (pasture).

Thus, the aim of this essay was evaluate the effects of supplementation with different relationship between carbohydrate and protein on performance of young bulls from 4 until 18 months of age.

Material and methods

Animals, experiment design and diets

The experimental protocol and procedures were approved by the Universidade Federal de Viçosa Animal Care and Use Committee.

This experiment was carried out at the beef cattle facility of the Universidade Federal de Viçosa, in Viçosa, MG, Brazil (20°45' S 42°52' W). The experimental area is located in a hilly area at an altitude of 670 m with an average slope of 34%.

This study was carried out between March of 2010 and April of 2011. The weather data is presented in Fig. 1. Animals were submitted to a period of 14 days for adaptation and a 430-days experimental period for evaluation of performance, divided into 4 phases: Phase 1= suckling phase in rainy-dry transition season (112days); Phase 2= post-weaning in dry season (84 days); Phase 3= post-weaning in the dry-rainy transition season (84 days); Phase 4= finishing phase in the rainy season (150 days).

Fifty-five beef calves with average initial body weight of 138.3 ± 3.4 kg and between 90 and 150 days of age and their dams (30 Nellore; 10 $\frac{1}{2}$ Nellore $\frac{1}{2}$ Holstein; 15 $\frac{3}{4}$ Nellore $\frac{1}{4}$ Holstein), were used. Only Nellore sires were used in this study. Two animals from each treatment in the end of phase 1 and one animal from each treatment in the end of phases 2 and 3 were randomly taken away from their groups to realize other measures.

The animals were housed in a 10-ha paddocks of signal grass (*Brachiaria decumbens*) in phase 1 and in 2.5-ha in others phases, provided with feeders covered with asbestos tiles and privative feeders for calves (0.5 m per animal) and drinkers. The nutritional plans which were randomly assigned to animals were: control = animals receiving mineral mixture only; HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement (Table 1). Approximately 50 and 25% of the protein requirement were supplied in high and low protein supplement, respectively, and about 30 and 15% of the

total digestible nutrients (TDN) requirement was supplied in high and low carbohydrate supplement, respectively. Half of the stipulated requirements were supplied by supplement in phase 1 due to the milk intake in this phase. The amount of supplement was adjusted every 28 days by using the estimated protein and energy requirement by BR-CORTE (Valadares et al. 2006), considering the weight gain in the adaptation period to first adjust of the supplementation and the previous 28 days' weight gain to adjust in the other periods.

The supplement composition was formulated for all supplements have similar protein profile with same proportion of protein from each ingredient (Table 2). The calves were supplemented once a day at 11 a.m. In order to minimize possible effects of paddocks on experimental treatments, the animals were rotated among the five pasture paddocks every seven days, allowing each group stay in each paddocks for the same period of time and intake similar pasture, differing only the supplement intake.

The calves were weaned after the end of phase 1, when they were about eight months, 112 days after the beginning of experimental period.

Experimental procedures and sampling

Forage samples were randomly taken, every 28 days, in order to evaluate the forage mass per hectare. In each plot, six forage samples were randomly selected by using a metal square (0.5 x 0.5 m) and cut at approximately 1 cm above the soil. After that, forage subsamples (200 g) were dried at 60°C for 72 hours and ground to pass through a 1-mm screen.

Every seven days, a manual grazing simulation was performed simultaneously to the observation of grazing behavior of the animals in order to obtain samples to evaluate chemical composition of the forage consumed by the animals. All samples were dried at

60°C for 72 hours, grounded to pass through 1-mm screen, and proportionally sub-sampled to a composite sample per period.

In order to evaluate forage intake and digestibility, digestion trial (eight days), was performed simultaneously to the evaluation of performance of animals in middle of each production phase. Fecal dry matter excretion was determined by using chromic oxide as external marker, 10, 12, 14 and 16 g/day to phases 1, 2, 3 and 4, respectively. These portions were packaged in a paper cartridge and directly introduced into the esophagus through a rubber tube. The animals received the marker once daily at 11 a.m., during the first seven days of the digestion trial. To evaluate individual intake of supplement 10, 12, 14 and 16 g/day of titanium dioxide were mixed on supplement and offered to animals in phases 1, 2, 3 and 4, respectively. The forage intake was estimated by using indigestible neutral detergent fiber (iNDF) as internal marker. After five days of adaptation, feces samples were collected at 3 p.m. on the 6th day, at 11 a.m. on the 7th day, and at 7 a.m. on the 8th day of the digestion trial period. The fecal samples were dried at 60 °C for 72 hours, grounded to pass through 1-mm screen sieve, and proportionally sub-sampled to a composite sample by phase.

Milk intake by calves was estimated on days 28, 56 and 84 of the experimental period (phase 1). Cows were separated from their calves at 6 p.m. At 6 a.m. of the next day, cows were milked immediately after an injection of 2 mL of oxytocin (10 IU/mL; Ocitovet®, Brazil) in the mammary vein and the produced milk was weight. The milking was planned to do not occur time longer than 2 hours from the first and the last cow milked. The exact time when each cow was milked was recorded and the milk production was converted into a 24-hours production. The milk produced was corrected to 4% of fat (4% fat-milk) calculated by the following equation (NRC 2001):

$$4\% \text{ fat-milk (kg)} = 0.4 \times (\text{milk production}) + [15 \times (\text{fat production} \times \text{milk production}/100)]$$

After 16h of fasting, the animals were weighted in the beginning and in the end of each phase.

Chemical analysis

Samples of forage, feces and supplement ingredients were analyzed for dry matter (DM, index no. 920.39), crude protein (CP, index no. 954.01), organic matter (OM, index no. 942.05) and ether extract (EE, index no. 920.39) as described by AOAC (Association of Official Analytical Chemists, 1990). Lignin content was obtained by cellulose solubilization in sulfuric acid (Van Soest & Robertson 1985). For analysis of neutral detergent fiber (apNDF) samples were treated with thermostable α -amylase without sodium sulfite and corrected for ash residue (Mertens, 2002) and residual nitrogen compounds (Licitra et al. 1996). The iNDF content was evaluated using F57 (Ankon®) bags incubated in rumen by 288 (Valente et al., 2011b). Fecal samples were evaluated for chromium and titanium dioxide content by using atomic absorption (Williams et al. 1962) and colorimetric (Myers et al., 2004) methods, respectively.

Content of non-fibrous carbohydrate, corrected for ash and protein (NFCap), was calculated by using the following equation (Detmann & Valadares Filho 2010):

$$\text{NFC} = 100 - [(\% \text{CP} - \% \text{CP urea} + \% \text{ of urea}) + \% \text{apNDF} + \% \text{EE} + \% \text{ash}]$$

Mass of forage samples obtained was analyzed for DM, as previously described. Milk was analyzed for protein, fat, lactose and total solids content, using spectroscopy (Foss MilkoScan FT120, Hillerød, Denmark).

The fecal excretion was estimated by ratio of the marker dose (chromic oxide) and its concentration in the feces.

The dry matter intake (DMI) was estimated by using the iNDF as an internal marker and calculated by the following equation:

$$\text{DMI (kg/day)} = [((\text{FE} \times \text{iNDF feces}) - \text{iNDF supplement}) \div \text{iNDF forage}] + \text{SI} + \text{MI},$$

Where FE is the fecal excretion (kg/day); iNDF feces is the concentration of iNDF in the feces (kg/kg); iNDF supplement is the iNDF in the supplement (kg); iNDF forage is the concentration of iNDF in forage (kg/kg); SI is the supplement intake and MI is the milk intake.

The estimation of the individual intake of supplement was obtained by using the external marker titanium oxide by using the following equation:

$$SI = (FE \times MCF) / MCS,$$

Where SI is the dry matter supplement intake (kg/day); FE is the fecal excretion (kg/day); MCF is the marker concentration in the feces (kg/kg); MCS is the marker concentration in the supplement (kg/kg).

Statistical analysis

This study was carried on using a completely randomized design using a 2 x 2 + 1 factorial arrangement to evaluate the nutritional plans (two protein levels, two carbohydrate levels and one control). Initial body weight of the calves and initial body weight and body condition score of the cow were used as covariate for the data analysis.

The variables will be evaluated according to a complete random design in a time repeated measures design by using mixed models methods according to the model (Kaps & Lamberson, 2004):

$$Y_{ijk} = \mu + P_i + F_j + (P \times F)_{ij} + \varepsilon_{ijk}$$

where Y_{ijk} is the response variable measured in the experimental unit k submitted to the nutritional plan i in the j phase; μ is the overall constant; P_i is the effect of the i nutritional plan (fixed effect); F_j is the effect if j performance phase (random effect); $(P \times F)_{ij}$ is the interaction between the principal effects (fixed effect); ε_{ijk} is the non-observable random error, presupposed by the normal distribution.

The best structures of matrix of (co)variance were defined by using the Akaike's information criteria. Significant difference was considered at $P < 0.05$. The data were analyzed by using the MIX procedure of SAS version 9.1

Results

The annual precipitation was about 1500 mm, out of which 90% occurred from October to March (Figure 1). Average forage mass throughout the experimental period was 3.88, 3.89, 3.06, 3.18 ton/ha in phase 1, 2, 3, and 4, respectively.

The crude protein (CP) of forage was affected by season, with 8.8, 5.5, 12.1, 10.7% CP in Phase 1, 2, 3, and 4, respectively (Table 2). Moreover, about 30% of CP was associated to fiber, being slowly available to ruminal microorganisms.

The average milk intake by calves was 6.2 kg/day. In phases 1, 2 and 3, the non-supplemented animals presented lower ($P < 0.05$) intake of DM and total digestible nutrients (TDN). Although differences in DM intake, in phase 4 (rainy season), were not observed ($P > 0.05$) between supplemented and non-supplemented animals, the supplemented animals presented greater TDN intake. In addition, all treatments presented greater ($P < 0.05$) intake of DM and TDN in the rainy season (phase 3 and 4) than in the dry season (phase 1 and 2) (Table 3).

The non-supplemented animals presented lower ($P < 0.05$) average daily gain (ADG) than supplemented animals in all phases (Table 4). In phases 1 and 4, differences were not observed ($P < 0.05$) among types of supplement. However, in phase 2, the nutritional plan with high protein and high carbohydrate (HPHC) presented greater ($P < 0.5$) performance. In addition, in phase 3, nutritional plan with high carbohydrate (HPHC and LPHC) presented greater ($P < 0.05$) performance. However, the nutritional plans with low carbohydrate (HPLC and LPLC) presented similar ($P > 0.05$) weight gain to the non-supplemented animals.

Animals presented better ($P<0.05$) performance in phases 1 and 4. The control animals presented the lowest ($P<0.05$) ADG in the dry season (phase 2). However, differences were not found ($P>0.05$) in performance of supplemented animals between dry season (phase 2) and dry-rainy transition phase (phase 3).

The supplemented animals presented final body weight 94.8, 69.2, 84.8 and 85.5 kg higher than control animals in HPHC, HPLC, LPHC and LPLC, respectively. Considering the additional gain regarded to Control animals of the best nutritional plan (HPHC) and ADG of control animals at post-weaning, the non-supplemented animals needed 258 more days to reach the weight of animals of HPHC animals at 18 months of age.

Nutritional plans with low supply of carbohydrate (HPLC and LPLC) had greater supplement use efficiency. Supplement use efficiency was greater (Table 3) for low-quality pastures (phase 1 and 2).

Discussion

Standing Forage and Forage Quality

The pasture presented high CP in rainy season, as expected for this season, being higher after the early rains, when the plants starting to grow and they are at the immature stage (Table 2). Nonetheless, in the early growth stage of a plant, a significant part of CP is non protein nitrogen (NPN) (Valente et al. 2011). Thus, the animal may have deficit of metabolic protein, even with a high intake of CP.

In tropical pastures, protein is the major limiting factors to production. Figueiras et al. (2010) proposed the value of 9% CP as value that optimizes the forage use by grazing cattle. However, performance increased as dietary protein increased, even when was higher than 9%. The animal response to supplementary protein occurred in all phases, including rainy season when pasture presents high CP levels. Thus, in phases

that pasture present low CP level the improvement of performance occur by supplying of quantity deficit of CP, but when pasture presents high CP level, the performance may be improved by supply of quality deficit, because in tropical plants, a significant amount of protein is associated to fiber as neutral detergent insolvent protein (NDIP) (Table 2) that is slowly available to ruminal microorganisms.

Forage mass was not greater in the rainy season. Although the plant had presented accelerated growth, the increase of grazing pressure, due to of growth of animals, prevented the accumulation of forage. However, if there is a minimum quantity of forage mass to supply animal demand, canopy structure and nutritive value are more important than forage mass to pasture intake. Thus, forage mass may present a secondary importance on animal performance. Casagrande et al. (2011) observed similar forage composition and animal performance when forage mass ranged by approximately 50%.

Feed intake

At early ages, calves get most energy and nutrients from milk. However, as they grow up, nutritional requirement of calves increases and milk intake reduces. Thus, the milk became insufficient to supply nutritional requirement of calves (Henriques et al. 2011) and a gradual replacement of milk by solid feeds takes place.

Milk and pasture were not sufficient to supply substrate demand to reach the genetic potential of calves and they responded to concentrate supplementation, corroborating with Valente et al. (2012).

In the dry season (phase 2), the pasture presented low protein contends. Thus, it is likely that non-supplemented animals presented low activity of rumen due to protein deficiency, which is in turn, limited by the DM intake at low levels. In this period, the energy extraction from fibrous-carbohydrates is limited, especially, due to deficit of

nitrogen compounds for the enzymatic systems of ruminal microorganisms (Sampaio et al., 2009; Detmann et al., 2009). However, nitrogen assimilation in rumen may be increased with jointly supplementation of CP and NFC (Detmann et al. 2005, Souza et al. 2010). Therefore, when animals were supplemented with protein, DM intake increased, which were intensified with jointly supplementation of protein and carbohydrate (HPHC).

The dry-rainy season transition period is characterized by a dramatic change of forage quality, with increase of availability of forage at immature physiological stage, presenting high CP level and high-quality NDF, with scarce content of lignin. In the rainy season, forage quality is improved with a consequent increase in the passage rate (Estrada et al. 2010), degradability of DM and intake of effectively degradable DM (Ortiz et al. 2010).

With the forage maturity, it occurs an increase of protein fraction associated to fiber that is slowly available and of protein fraction associated to fiber that is unavailable (Costa et al. 2011b). Therefore, the protein available to animals reduces with plant maturity. Nonetheless, in grazing system with stable stocking rate, it is difficult to keep plants in immature stages. Thus, when protein supplement is supplied, the protein available in ruminal environment is increased and, therefore, rumen kinetic characteristics and intake of digestible DM are improved.

Although supplemented animals presented greater performance when pasture presented high CP level (phase 3 and 4), the total DM intake was not improved with supplementation. A partial substitution of pasture intake by supplement occurred. However, the supplementation may have improved available energy and nutrients to animal, even if there were no changes in the consumption, being confirmed by increased of TDN (Table 3).

In the rainy season (phase 4), similarly to other studies (Zervoudakis et al. 2008, Costa et al. 2011a), the protein supplementation did not change DM intake. Although protein supplementation increases NDF degradation rate (Costa et al. 2011b), no changes occur in DM intake. Therefore, rumen repletion does not determine the consumption in this season, being the physiologic or metabolic mechanisms the likely controllers of consumption (Detmann et al. 2009).

Performance and efficiency of supplement use

Substitutive effect occurs when supplement intake reduces forage intake. Despite being more intensely observed in energy supplementation (Souza et al., 2010), the substitutive effect may occur when high levels of protein supplement is offered in a short period of time (Sampaio et al. 2010b). Thus, substitution of forage nutrients by supplement nutrients might explain the lack of increase in performance of the animals with an increase in the level of carbohydrate intake (HPHC and LPHC), even when it was increased the jointly supplementation of carbohydrate and protein (HPHC). However, differently from the other phases, in phase 2 (dry season), high levels of jointly supplementation of carbohydrate and protein (HPHC) improve the performance. A plausible explanation is that in phase 2 the HPHC presented an appropriate balance of protein and energy, where occurred supplied of protein deficit of pasture with appropriate energy offer allowing an efficient utilization of protein (Souza et al. 2010) and thus a greater availability of metabolizable energy and protein to animal. Protein supplementation implies in changes in forage intake, availability of dietary energy, quantity of biochemical precursor to microbial and animal metabolism and consequently, may determine animal performance (Detmann et al. 2011).

Although the supply of high levels of carbohydrate could increase total energy intake, it did not improve of performance. It is likely that the substitute effect caused by

NFC intake reduced forage utilization (Souza et al. 2010). On this condition, occur competition between fibrolytic and non-fibrolytic microbial species for essential nutrients (Carvalho et al. 2011) and a reduction in fiber utilization (Costa et al. 2008). Thus, carbohydrate supplementation caused a partial substitution of pasture intake by supplement intake (Table 3) with a small increase in the total energy available to animal.

Supplementation improved the performance of suckling calves (phase 1). Multiple supplementation increases intake and digestibility of calves (Sampaio et al. 2010a). Thus, it also increases the amount of nutrients and metabolizable energy that allows an increment of muscle and fat tissue deposition by the animal.

Strategies such as creep-feeding, which allows access of calves to concentrate at early stage, have been successfully used to progressively reduce nutritional and social dependence of the calf on the cow (Enríquez et al. 2011). Thus, one of the main reasons for performance improvement might be a better ruminal condition at early stage of development which allows a better grazing efficiency before and after weaning.

In phase 1, all supplemented animals presented similar performance. Probably, all supplements were able to increase energy and nutrients intake of calves to appropriated levels. However, Sampaio et al. (2010a) observed greater weight gain and nutritional characteristics of suckling calves that received protein-energy supplement than energy supplement (90 % corn) and protein supplement (85% soybean meal).

Level of CP of forage in the dry season (phase 2) was very low (5.5 %) (Table 2). Therefore, the energy extraction from fibrous carbohydrate was limited by CP deficit to enzymatic systems of ruminal microorganisms (Sampaio et al., 2009; Detmann et al., 2009). Thus, animal performance increased when protein was supplied. However, performance improved when high level of protein (HPHC and HPLC) was supplied. Adjustments of nutritional deficits of pasture by multiple supplementation, increases

degradation rate (Oliveira et al. 2010, Detmann et al. 2011), decreases the discrete latency of NDF in rumen (Detmann et al., 2011) and increases of passage rate, and thus, increases the intake (Oliveira et al. 2010) and the availability of digestible substrate to animal.

Mateus et al. (2011), when studying the effect of energy levels on steers in tropical pasture in dry season, found a quadratic effect on weight gain with the maximum point with 0.5 % BW (18.5 % CP). The total digestible nutrients (TDN) was not increased with supplement levels above 0.5%, and it is likely that above this value the increase of supplement level was similar to reduction of pasture intake. In addition, Figueiredo et al. (2011), when studying the effect of energy levels to heifers in tropical pasture in rainy season, found a positive linear effect on ADG without variation in DM intake, but TDN intake increased with level of supplementation. Thus, we may observe that supplements provide different responses in function of season or pasture quality.

Although the pastures presented greater quality in dry-rainy transition season (phase 3) than in dry season (phase 2) (Table 2), the supplemented animals presented similar performance in both seasons. After the early rains, CP level of forage increase, but a significant part of this CP is in form of non-protein nitrogen. In addition, animals prefer to consume sprouts in detriment to mature part of plant, increasing grazing time, due to the increase in time spent selecting (Valente et al. 2011). Thus, abrupt change of diet and behaviour usually impair the performance (Valente et al. 2011).

Traditionally, Brazilian producers believe that pasture presents great quality and it is able to appropriately supply the nutrients to cattle in rainy season and is not necessary the supplementation of the livestock. However, in this work, supplemented animals presented additional gain of 0.178 kg/day to non-supplemented animals, corroborating to Tonello et al. (2011), who, in a metanalysis study of Brazilian works, found additional gains of 0.152 kg/day for supplemented animals.

In the rainy season, tropical pasture presented energy/protein relationship upper than demanded by cattle, implying in a relative excess of energy in relation to protein (Detmann et al., 2010). Therefore, protein supplementation may balance the energy/protein relationship for the metabolic requirement and improve performance.

The supplementation as a function of nutritional requirement, which is in turn, determined by weight gain rate, allowed a low supplement level in periods when the pasture presented low potential to supply nutritional demands, and high level of supplement when pasture presented high quality, thus it occurred high efficiency of supplement use.

It is likely that, in phases 1 and 2, the offer of multiple supplements were nearly to the level needed to supply the nutritional forage deficit and occurred a high efficiency of supplement use. However, in phases 3 and 4, the pasture presented high protein level (Table 2), thus the supplements acted to balance nutrients in the rumen and directly supply substrates to the animal, with a decrease in the efficiency of supplement use. Although it presented a lower efficiency in phases 3 and 4, multiple supplementation was important to increase weight gain rate and to allow slaughter of animals in the end of the rainy season, at 18 months of age.

Conclusions

Although non-supplemented animals present similar total dry matter intake in the rainy season, supplementation increases performance of young bulls belong the productive cycle. However, nutritional plans that provide low amount of carbohydrate (until 15% of TDN requirements) have greater efficiency of supplement use.

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Table 1 Composition of supplement

	Nutritional plan ¹				
	Control	HPHC	HPLC	LPHC	LPLC
Corn	-	55.0	0.0	83.5	53.0
Corn gluten	-	3.0	20.0	0.0	14.0
Soybean meal	-	37.0	70.0	12.0	24.0
Urea/ A.S. ²	-	1.0	2.0	0.5	1.0
MM ³	100	4.0	8.0	4.0	8.0

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement. ² Urea + ammonia sulfate (9:1). ³ Mineral mixture; composition: calcium: 8.7 %, phosphor: 9.0 %, sulfur: 9.0 %, sodium: 18.7 %, zinc: 2400.00 mg/kg, copper: 800.00 mg/kg, manganese: 1600.00 mg/kg, iodine: 40.00 mg/kg, cobalt: 8.00 mg/kg, selenium: 8,16 mg/kg.

Table 2 Chemical composition of supplement and pasture

	Supplement ¹				Pasture ²			
	Control	HPHC	HPLC	LPHC	Phase 1	Phase 2	Phase 3	Phase 4
Dry matter	87.1	89.5	85.8	87.0	29.6	42.5	28.0	21.3
Organic matter	89.3	87.4	88.4	85.8	91.4	92.4	92.4	91.5
Crude protein	29.2	55.3	15.4	29.5	8.8	5.5	12.1	10.7
apNDF ³	8.7	10.2	7.4	9.2	65.3	65.0	61.5	61.6
Ether Extract	2.6	1.5	3.0	2.4	1.2	1.2	1.5	1.2
CNF ⁴	46.2	23.3	57.2	43.6	16.1	20.7	17.3	17.9
Lignin ⁵	0.4	0.8	0.2	0.3	4.9	4.4	3.6	2.7

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement.

² Obtained by handle plucked sampling; Phase 1= suckling phase in rainy-dry transition season (112days); Phase 2= post-weaning in dry season (84 days); Phase 3= post-weaning in the dry-rainy transition season (84 days); Phase 4= finishing phase in the rainy season (150 days).

³ Neutral detergent fiber corrected for ash and protein.

⁴ Non-fibrous carbohydrates.

⁵ Corrected for ash.

Table 3 Intake of supplement, total dry matter and total digestible nutrients (TDN) and efficiency of supplement use

Nutritional plans	Production phase			
	Phase 1	Phase 2	Phase 3	Phase 4
Supplement intake (kg)				
Control	-	-	-	-
HPHC	0.734	0.946	0.996	1.758
HPLC	0.344	0.504	0.511	0.771
LPHC	0.671	0.934	0.856	1.768
LPLC	0.353	0.449	0.477	0.793
SE	0.09	0.10	0.12	0.12
Total dry matter intake (g/kg BW)				
Control	14.68Bb	13.14Bb	21.63Ba	20.66a
HPHC	17.58Ac	19.30Abc	23.10ABa	20.59ab
HPLC	18.28Ab	16.20ABb	24.78Aa	21.91a
LPHC	17.06BAb	17.50Ab	23.69ABa	19.52b
LPLC	15.66ABc	16.70Abc	23.44ABa	18.87ab
SE	1.00	1.10	1.20	1.40
TDN intake (g/kg BW)				
Control	11.04Ba	7.44Cb	12.43Ba	10.88Ba
HPHC	13.91Aa	11.88Ab	14.99Aa	13.18ABa
HPLC	13.48ABab	9.85ABc	15.77Aa	13.49Ab
LPHC	12.11ABab	10.55ABb	14.19ABa	12.05ABab
LPLC	11,87Bb	9.69Bc	14.26ABa	12.52ABab
SE	0.68	0.76	0.82	0.97
Efficiency of supplement use (kg/kg)				
Control	-	-	-	-
HPHC	0.280	0.383	0.112	0.102
HPLC	0.430	0.550	0.170	0.167
LPHC	0.322	0.244	0.153	0.117
LPLC	0.575	0.483	0.161	0.247
SE	0.09	0.10	0.10	0.11

Different subscript lowercase letters within a row denote significant difference according to period ($P < 0.05$) and different subscript capital letters within a column denote significant difference according to nutritional plans ($P < 0.05$).

Table 4 Least square means and standard error (SE) for final body weight and average daily gain (ADG) of young bulls according to the nutrition plan and production phase

Nutritional plans	Production phase			
	Phase 1	Phase 2	Phase 3	Phase 4
Final Body weight (kg)				
Control	208.1c	220.6Bc	248.5Bb	343.5Ba
HPHC	231.3d	278.3Ac	312.9Ab	438.3Aa
HPLC	224.0d	264.2Ac	302.3Ab	412.7Aa
LPHC	232.9d	264.7Ac	305.1Ab	428.3Aa
LPLC	228.6d	261.0Ac	306.7Ab	429.3Aa
SE	10.46	11.56	12.27	13.11
ADG (kg/day)				
Control	0.613Ba	0.141Cc	0.346Bb	0.617Ba
HPHC	0.818Aa	0.503Ab	0.458Ab	0.796Aa
HPLC	0.761Aa	0.418ABb	0.433ABb	0.746Aa
LPHC	0.829Aa	0.369Bb	0.477Ab	0.823Aa
LPLC	0.816Aa	0.358Bb	0.423ABb	0.813Aa
SE	0.03	0.03	0.03	0.04

Different subscript lowercase letters within a row denote significant difference according to period ($P < 0.05$) and different subscript capital letters within a column denote significant difference according to nutritional plans ($P < 0.05$).

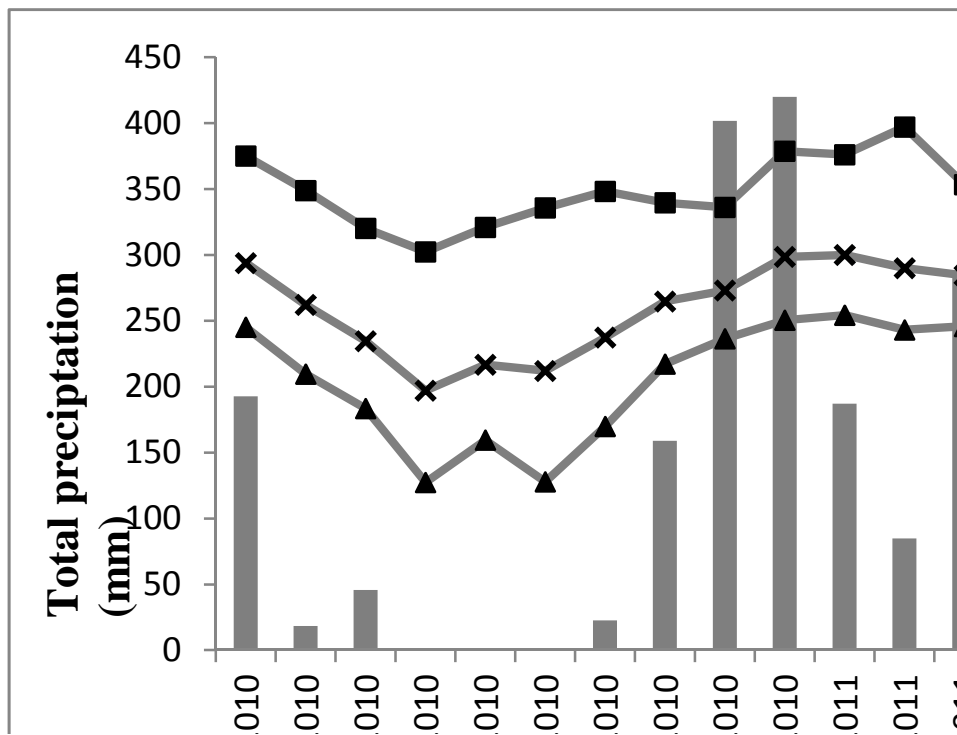


Fig. 1 Precipitation, average temperature (Average T.), maximum temperature (Maximum T.) and minimum temperature (Minimum T.) belong the experimental period.

Nutritional evaluation of young bulls receiving supplements with different ratios of protein: carbohydrate from suckling phase until the fattening

Abstract The aims of this work were evaluate the intake and digestibility of young bulls supplemented with different ratios of protein: carbohydrates in tropical pastures from 4 until 18 months. Fifty five beef calves (138.3 ± 3.4 kg, 90-150 days of age) and their dams were used. The animals were subjected to 430 days of experimental period, encompassing 4 seasons. The treatments consisted of 5 nutritional plans: control = calves receiving only mineral mixture; HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement. The amount of supplement was adjust every 28 days. Dry matter (DM) intake was higher ($P < 0.05$) in dry to rain transition and rain seasons for all nutritional plans. Non-supplemented calves had lower ($P < 0.05$) intake of DM and total digestible nutrients (TDN) than supplemented calves in all seasons with exception in rain season. Although differences on DM intake was not observed ($P > 0.05$) between supplemented animals, the supplements with high carbohydrate (HPHC and LPHC) had lower ($P < 0.05$) forage intake ($P < 0.05$) in the suckling phase (rain to dry transition season) and in the rain season. However, the HPHC plan had higher ($P < 0.05$) intake and digestibility of neutral detergent fiber. It can be concluded that the effects of supplementation type on nutrition characteristics suffer interaction with season. Supplement with high protein level (supplying 50% CP requirement) increase intake and digestibility of diet, being more intense when associate with high carbohydrate level (supplying 30% TDN requirement). On other hand, supplement with low protein level (supplying 25% CP requirement) and high carbohydrate level decrease DM intake and fiber digestibility, occurring more intense in rainy season.

Introduction

Modern systems of production aim continuous growth and slaughter young animals. Thus, strategic supplementation, where supply limiting nutrients and increase pasture use, is an important way to get this aim providing condition to increase weight gain belongs the year (Tonello et al. 2011).

Food intake by ruminants is wide complex, integrated mechanisms have been proposed considering multifactorial view, including factors associated with minimization of animal discomfort (Forbes, 2007). Due the complexity and difficulty the measure the intake by beef cattle in tropical pasture, the results obtained until now have been variables.

Dietetic protein has been the main limiting to utilization of tropical pasture by beef cattle in dry season (Goes et al. 2010, Porto et al. 2011, Valente et al. 2011) when the dormancy stage of plant decrease protein content in pasture. However, several researchers also has found improvement of nutritional characteristics with protein supplementation in rainy season (Goes et al. 2010, Porto et al. 2011, Valente et al. 2011), even plant in a growth stage, due to association of protein with fiber (Costa et al. 2011) decreasing the availability of protein to ruminal microorganisms and to animal.

The relation protein: carbohydrate in supplement determines interactive effects on intake and digestibility of diet (Souza et al. 2010). However, the intensity of these effects is determined by composition of basal diet (pasture) that fluctuate through the year. The supplementation may increase the availability of energy and protein to animal by improvement of ruminal condition and greater extraction of energy and

nutrients from pasture or/and directly by substrates supply to animal metabolism (Valente et al. 2011).

There are few works that evaluate beef cattle belong of productive cycle or that compare of supplements between seasons. The lack of information about nutritional characteristics belong production cycle has limited the application of technology developed in experimental conditions by commercial systems of production. Thus, the aims of this work were evaluate the intake and digestibility of young bulls supplemented with different ratios of protein: carbohydrates in tropical pastures from 4 until 18 months.

Material and methods

Animals, experimental design and diets

The experimental protocol and procedures were approved by the Universidade Federal de Viçosa Animal Care and Use Committee.

This experiment was carried out at the beef cattle facility of the Universidade Federal de Viçosa, in Viçosa, MG, Brazil (20°45' S 42°52' W). The experimental area is located in a hilly area at an altitude of 670 m with an average slope of 34%.

This study was carried out between March of 2010 and April of 2011. The weather data are presented in Fig. 1. The calves were submitted to a period of 15 d of adaptation and a 430-d experimental period divided into four phases: phase 1 = suckling phase in rainy-dry transition season (112days); phase 2 = post-weaning in dry season (84 days); phase 3 = post-weaning in the dry-rainy transition season (84 days); phase 4 = fattening phase in the rainy season (150 days).

Fifty-five beef calves with average initial body weight of 138.3 ± 3.4 kg and between 90 and 150 days of age and their dams (30 Nellore; 10 $\frac{1}{2}$ Nellore $\frac{1}{2}$ Holstein; 15 $\frac{3}{4}$ Nellore $\frac{1}{4}$ Holstein), were used. Only Nellore sires were used in this study. Two

animals from each treatment in the end of phase 1 and one animal from each treatment in the end of phases 2 and 3 were randomly taken away from their groups to realize other measures.

The animals were housed in a 10-ha paddocks of signal grass (*Brachiaria decumbens*) in phase 1 and in 2.5-ha in others phases, provided with feeders covered with asbestos tiles and privative feeders for calves (0.5 m per animal) and drinkers. The nutritional plans which were randomly assigned to animals were: control = animals receiving mineral mixture only; HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement (Table 1). Approximately 50 and 25% of the protein requirement were supplied in high and low protein supplement, respectively, and about 30 and 15% of the total digestible nutrients (TDN) requirement was supplied in high and low carbohydrate supplement, respectively. Half of the stipulated requirements were supplied by supplement in phase 1 due to the milk intake in this phase. The amount of supplement was adjusted every 28 days by using the estimated protein and energy requirement by BR-CORTE (Valadares et al. 2006), considering the weight gain in the adaptation period to first adjust of the supplementation and the previous 28 days' weight gain to adjust in the other periods.

The supplement composition was formulated for all supplements have similar protein profile with same proportion of protein from each ingredient (Table 2). The calves were supplemented once a day at 11 a.m. In order to minimize possible effects of paddocks on experimental treatments, the animals were rotated among the five pasture paddocks every seven days, allowing each group stay in each paddocks for the same period of time and intake similar pasture, differing only the supplement intake.

The calves were weaned after the end of phase 1, when they were about eight months, 112 days after the beginning of experimental period.

Experimental procedures and sampling

Forage samples were randomly taken, every 28 days, in order to evaluate the forage mass per hectare. In each paddocks, six forage samples were randomly selected by using a metal square (0.5 x 0.5 m) and cut at approximately 1 cm above the soil. After that, forage subsamples (200 g) were dried at 60°C for 72 hours and ground to pass through a 1-mm screen sieve.

Handle plucking sample of pasture was taken every seven days simultaneously to the observation of grazing behavior of the animals in order to obtain samples to evaluate chemical composition of the forage intake. All samples were dried at 60°C for 72 hours, grounded to pass through 1-mm screen sieve and proportionally sub-sampled to composite a sample per period.

In order to evaluate forage intake and digestibility, digestion trial (eight days), was performed simultaneously to the evaluation of performance of animals in middle of each production phase. Fecal dry matter excretion was determined by using chromic oxide as external marker, 10, 12, 14 and 16 g/day to phases 1, 2, 3 and 4, respectively. These portions were packaged in a paper cartridge and directly introduced into the esophagus through a rubber tube. The animals received the marker once daily at 11 a.m., during the first seven days of the digestion trial. To evaluate individual intake of supplement 10, 12, 14 and 16 g/day of titanium dioxide were mixed on supplement and offered to animals in phases 1, 2, 3 and 4, respectively. The forage intake was estimated by using indigestible neutral detergent fiber (iNDF) as internal marker. After five days of adaptation, feces samples were collected at 3 p.m. on the 6th day, at 11 a.m. on the 7th day, and at 7 a.m. on the 8th day of the digestion trial period. The fecal samples were

dried at 60 °C for 72 hours, grounded to pass through 1-mm screen sieve, and proportionally sub-sampled to a composite sample by phase.

Milk intake by calves was estimated on days 28, 56 and 84 of the experimental period (phase 1). Cows were separated from their calves at 6 p.m. At 6 a.m. of the next day, cows were milked immediately after an injection of 2 mL of oxytocin (10 IU/mL; Ocitovet®, Brazil) in the mammary vein and the produced milk was weight. The milking was planned to do not occur time longer than 2 hours from the first and the last cow milked. The exact time when each cow was milked was recorded and the milk production was converted into a 24-hours production. The milk produced was corrected to 4% of fat (4% fat-milk) calculated by the following equation (NRC 2001):

$$4\% \text{ fat-milk (kg)} = 0.4 \times (\text{milk production}) + [15 \times (\text{fat production} \times \text{milk production}/100)$$

After 16h of fasting, the animals were weighted in the beginning and in the end of each phase.

Chemical analysis

Samples of forage, feces and supplement ingredients were analyzed for dry matter (DM, index no. 920.39), crude protein (CP, index no. 954.01), organic matter (OM, index no. 942.05) and ether extract (EE, index no. 920.39) as described by AOAC (Association of Official Analytical Chemists, 1990). Lignin content was obtained by cellulose solubilization in sulfuric acid (Van Soest & Robertson 1985). For analysis of neutral detergent fiber (aNDF) samples were treated with thermostable α -amylase without sodium sulfite and corrected for ash residue (Mertens, 2002) and residual nitrogen compounds (Licitra et al. 1996). The iNDF content was evaluated using F57 (Ankon®) bags incubated in rumen by 288 (Valente et al., 2011b). Fecal samples were

evaluated for chromium and titanium dioxide content by using atomic absorption (Williams et al. 1962) and colorimetric (Myers et al., 2004) methods, respectively.

Content of non-fibrous carbohydrate, corrected for ash and protein (NFCap), was calculated by using the following equation (Detmann & Valadares Filho 2010):

$$\text{NFC} = 100 - [(\% \text{CP} - \% \text{CP urea} + \% \text{ of urea}) + \% \text{apNDF} + \% \text{EE} + \% \text{ash}]$$

Mass of forage samples obtained was analyzed for DM, as previously described. Milk was analyzed for protein, fat, lactose and total solids content, using spectroscopy (Foss MilkoScan FT120, Hillerød, Denmark).

The fecal excretion was estimated by ratio of the marker dose (chromic oxide) and its concentration in the feces.

The dry matter intake (DMI) was estimated by using the iNDF as an internal marker and calculated by the following equation:

$$\text{DMI (kg/day)} = [((\text{FE} \times \text{iNDF feces}) - \text{iNDF supplement}) \div \text{iNDF forage}] + \text{SI} + \text{MI},$$

Where FE is the fecal excretion (kg/day); iNDF feces is the concentration of iNDF in the feces (kg/kg); iNDF supplement is the iNDF in the supplement (kg); iNDF forage is the concentration of iNDF in forage (kg/kg); SI is the supplement intake and MI is the milk intake.

The estimation of the individual intake of supplement was obtained by using the external marker titanium oxide by using the following equation:

$$\text{SI} = (\text{FE} \times \text{MCF}) / \text{MCS},$$

Where SI is the dry matter supplement intake (kg/day); FE is the fecal excretion (kg/day); MCF is the marker concentration in the feces (kg/kg); MCS is the marker concentration in the supplement (kg/kg).

Statistical analysis

This study was carried on using a completely randomized design using a 2 x 2 + 1 factorial arrangement to evaluate the nutritional plans (two protein levels, two carbohydrate levels and one control). The variables will be evaluated according to a complete random design in repeated measures over time design by using mixed models method according to the model (Kaps & Lamberson, 2004):

$$Y_{ijk} = \mu + P_i + a_{ij} + F_j + (P \times F)_{ij} + \varepsilon_{ijk}$$

where Y_{ijk} is the response variable measured in the experimental unit k submitted to the nutritional plan i in the j phase; μ is the overall constant; P_i is the effect of the i nutritional plan (fixed effect); a_{ij} = effect of animal j within nutritional plan i (random effect); F_j is the effect if j performance phase (fixed effect); $(P \times F)_{ij}$ is the interaction between the principal effects (fixed effect); ε_{ijk} is the non-observable random error, presupposed with normal distribution.

The best structures of matrix of (co)variance were defined by using the Akaike's information criteria. Significant difference was considered at $P < 0.05$. The data were analyzed by using the MIX procedure of SAS version 9.1 (SAS Institute, Inc).

Results

The annual precipitation was about 1500 mm, out of which 90% occurred from October to March (Fig. 1). Average forage mass throughout the experimental period was 3.88, 3.89, 3.06, 3.18 ton/ha in phases 1, 2, 3, and 4, respectively.

The crude protein (CP) of forage was affected by season, with 8.8, 5.5, 12.1, 10.7% CP in phases 1, 2, 3, and 4, respectively (Table 2). Moreover, about 25% of CP was associated to fiber, being slowly available to ruminal microorganisms.

The calves had greater ($P < 0.05$) average daily gain (ADG) in phases 1 and 4 (rainy seasons). Non-supplemented animals (control) had lower ($P < 0.05$) ADG than

supplemented animals in all phases and consequently lower initial weight in phases 2, 3 and 4 (Table 3). The intake was expressed in function of body weight, becoming suitable for comparison between treatments along the experimental phases.

The average milk intake by calves was 6.2 kg/day. Non-supplemented animals had lower ($P < 0.05$) crude protein (CP) than animals that received high protein (HPHC and HPLC) in every phase and than supplemented animals in phases 1 and 2 (Table 4).

Only animals that received supplements with high protein (HPHC and HPLC) had greater ($P < 0.05$) intake of DM than control animals in the suckling phase (phase 1). However, only the supplement with high protein and high carbohydrate (HPHC) provided intake of dry matter of pasture (DMP) similar ($P > 0.05$) to control animals and increased ($P < 0.05$) intake of total digestible nutrients (TDN) (Table 4).

Although supplemented and non-supplemented animals had had similar intake of DMP ($P > 0.05$) in the dry season (phase 2), all supplemented animals had greater ($P < 0.05$) intake of DM and TDN than non-supplemented. However, only animals from the HPHC group had increased ($P < 0.05$) intake of NDF (Table 4).

Supplementation did not affect ($P > 0.05$) intake of pasture in the dry-rainy transition season (phase 3). However, only animals from the HPLC group had increased ($P < 0.05$) intake of DM with the supplementation and only animals that received high protein (HPHC and HPLC) had intake of TDN greater ($P < 0.05$) than non-supplemented animals.

Significant differences were not found ($P > 0.05$) in the intake of DM and TDN between the nutritional plans in the rainy season (phase 4). Moreover, there was a tendency ($P = 0.08$) of increased intake of TDN with high protein supplements (HPHC, $P = 0.14$; HPLC, $P = 0.08$) (Table 4). Pasture intake was lower ($P < 0.05$) for nutritional plans with high carbohydrate (HPHC and LPHC) in comparison with nutritional plans with low carbohydrate (HPLC and LPLC) and with the control. In addition, animals that intake

supplement with low protein and high carbohydrate (LPHC, 15% CP) had lower ($P<0.05$) intake of NDF than animals that intake supplement with high protein and low carbohydrate (HPLC, 55% CP).

The supplement with high protein and high carbohydrate (HPHC) provided greater ($P<0.05$) digestibility of DM and content of TDN than the others supplement in suckling phase. On other hand, supplement with low protein and high carbohydrate (LPHC) provided lower ($P<0.05$) digestibility of NDF and TDN content than control and the others supplements (Table 5).

Calves from control and HPHC groups had greater ($P>0.05$) NDF digestibility in dry season (phase 2). However, control group had lower ($P<0.05$) DM digestibility. In addition, the nutritional plan with low protein and high carbohydrate (LPHC) had lower NDF digestibility, but differences in TDN content were not observed ($P>0.05$) between supplemented calves (Table 5).

The calves that received nutritional plans with supplements with high protein (HPHC and HPLC) had greater ($P<0.05$) digestibility of DM and NDF and greater ($P<0.05$) TDN content than other nutritional plans in dry-rainy transition season. Although LPLC supplement had provided greater ($P<0.05$) DM digestibility than control, the supplements with low protein (LPHC and LPLC) did not differ ($P>0.05$) on NDF digestibility and TDN content in comparison with control (Table 5).

The supplemented calves had greater ($P<0.05$) DM digestibility than control calves in rainy season (phase 4). Moreover, nutritional plans with supplement with high protein and high carbohydrate (HPHC) and with low protein and low carbohydrate (LPLC) had the greatest ($P<0.05$) NDF digestibility. However, only HPHC had greater ($P<0.05$) TDN content than control.

Comparing the productive phases, it was observed greater ($P<0.05$) CP intake in phase 3, following by phases 1 and 4, and lower ($P<0.05$) in phase 2. All nutritional

plans had similar ($P>0.05$) DM intake in the phases 3 and 4, exception of the animals from LPHC that had greater ($P<0.05$) DM intake in the phase 3 than the phase 4. Intake of TDN was similar ($P>0.05$) between phases 1, 3 and 4, and lower ($P<0.05$) in the phase 2. However, pasture intake in the phase 3 was greater ($P<0.05$) than in the phase 4, and lowest ($P<0.05$) pasture intake was observed in the phases 1 and 2 (Table 4).

The digestibility of DM and CP was greatest ($P<0.05$) in the suckling phase (phase 1, rainy to dry transition season), following by the phase 4 (rainy season) and phase 3 (dry to rainy transition), and lowest ($P<0.05$) in the phase 2 (dry season). However, there was interaction between phase and nutritional plans. Only animals from the HPHC has greater ($P<0.05$) DM digestibility in the phase 3 than phase 2. Although differences were not found ($P<0.05$) in the DM digestibility between phases 3 and 4 to supplement with high protein (HPHC and HPLC), supplements with low protein (LPHC and LPLC) had lower DM digestibility ($P<0.05$) in the phase 3 in comparison to phase 4.

Discussion

Phase 1

The milk intake by calves found in this essay (6.2 kg/day) was higher than 5 and 5.5 kg/day found by Oliveira et al. (2007) and Valente et al. (2012a), respectively. Although calves had high milk intake and pasture had moderate CP content (8.8% CP, Table 2), the intake of high protein supplement (HPHC and HPLC) increased the DM intake, agreeing with theory that there is response to protein supplementary to cattle grazing even when the CP in diet seems adequate. The amino acid profile of CP in the diet, as well the balance between AA absorbed and ME availability may determine metabolic use of metabolites and feed intake (Greenwood and Titgemeyer 2000). On other hand, ruminal microorganisms have a specific nutrients requirement, thus the

protein and energy balance in rumen may affect nutritional characteristics (Souza et al. 2010). Thus, animals that received nutritional plans with high protein and high carbohydrate supplement (HPHC) had greater intake of pasture and TDN, and DM digestibility. On other hand, energetic supplement (supplement with low protein and high carbohydrate, LPHC) decreased fiber digestibility. The reduction of fiber use by cattle grazing tropical pastures receiving energetic supplement occur mainly due to modification of microorganisms population (Souza et al., 2010, Carvalho et al., 2011).

These results obtained in suckling phase seems contradictory with supplement type adopted by tradition production systems in tropical pastures, which is common utilize information from temperate condition, where usually use energetic supplement (14-16% CP) in creep feeding (Ralston et al. 2005). Similarly to this essay, Sampaio et al. (2010) found greater intake and digestibility of DM to calves that received protein-energetic supplement than calves that received energetic supplement, although the energetic supplementation had had improved nutritional characteristics in relation to non-supplemented animals.

Phase 2

The supplementation provided additive effect in total feed intake during the dry season. Protein supplementation improves DM intake and digestibility of low quality forage improving the N retention (Bohnert et al. 2011).

The supplementation with high protein and high carbohydrate (HPHC) provided the best balance of protein and energy between the supplements and had greater efficiency in pasture use with greater intake and digestibility of NDF. Thus, evidenced that do not only amount of supplement affects nutritional characteristics, as ratio of protein and energy in supplement may also affect (Souza et al. 2010).

Extraction of energy from fibrous carbohydrates in dry season become limited by lack of nitrogen compounds to synthesis of enzymatic systems of ruminal microorganisms (Sampaio et al. 2009, Detmann et al. 2009, Valente et al. 2011). Protein supplementation increase degradation rate and decrease discrete latency time of potential digestible NDF in rumen (Detmann et al., 2011). Oliveira et al., 2010 observed increase of DM degradability, degradation of NDF and DM, and passage rate with protein supplementation. However, in this essay occurred differences between the protein supplements on degradation of dietetic fractions. Thus, simplifications of nutritional process, considering only CP supply may result in mistaken information.

Energetic supplements usually increase amount of total energy intake, mainly by directly supply energy from supplement, since normally there is not increase in pasture intake (Figueiredo et al. 2011). Corroborating with this affirmation, the energetic supplement (LPHC) provided lower fiber digestibility with similar TDN intake when compare with the others supplements.

Phase 3

Although pasture had high protein content (12.1% CP) in dry to rainy transition season (Table 2), supplement with high protein (HPHC) increased digestibility of DM and NDF and TDN content in diet (Table 5). The maintenance or increase of NDF digestibility with supplementation prevented substitutive effects and allowed increased of energy intake without reduction of pasture intake. Expressive part of CP in tropical pasture during dry to rainy transition season are in non-protein nitrogen form (Valente et al. 2011), thus may occur low availability of protein nitrogen to ruminal microorganisms and of metabolic protein to host.

Only the supplement with high protein and low carbohydrate (HPLC, 55% CP) provided increase of DM intake (Table 4). The supply of energetic supplements increase

amount of substrates to growth of non-fibrolytic bacteria, and in this situation, fibrolytic bacteria, that have slower growth rate, have reduction of competitively (Carvalho et al., 2011) and may occur decrease of pasture utilization (intake and degradability). Corroborating with this premise, the animals that received energetic supplement (LPHC, 15% CP) had trend to decrease NDF digestibility. Supplementation with non-fibrous carbohydrate (NFC) may provide better assimilation of nitrogen composites of fast degradation in ruminal environment (Detmann et al., 2005). However, similarly to dry season (phase 2), balance of energy and protein in supplement was determinant to nutritional characteristics. Although supplementation with high carbohydrate and high protein (HPHC) had increased NDF digestibility, the supplementation with low protein and high carbohydrate (LPHC) decreased NFD digestibility. Thus, more important that amount of substrates (protein and energy) the balances between them determine the interaction between microbial populations in rumen (Carvalho et al. 2011) and the microbial digestive process.

Phase 4

Even supplementation provided increase in the DM digestibility in rainy season, all nutritional plans had similar intake of DM and TDN. However, supplemented animals had tendency to increase TDN intake. Although some author (Nascimento et al. 2010, Figueiredo et al. 2011) had observed increase in TDN intake without changes in DM intake, other authors observed no changes in intake of TDN, DM and pasture (Figueiredo et al. 2008, Barros et al. 2011) or decrease of pasture intake (Porto et al. 2008) with supplementation. Thus, differences in experimental results are mainly due to composition and amount of supplements offer to grazing cattle.

The decrease in pasture intake with high carbohydrate (HPHC and LPHC) occurred due to decrease in fiber digestibility that is mainly related to competition

effects between ruminal microorganisms (Carvalho et al. 2011), specially when use energetic supplement (Poppi & McLennan 1995). Moreover, only supplements with about 30% CP (HPLC and LPLC) improve TDN content in diet (Table 4), fortifying the idea that supplement composition as well the supplement amount establish the intake and utilization of diet by grazing cattle.

Tropical pastures have ratio energy: protein above of animals demand in rainy season, implying in relative excess of energy in relation to protein (Detmann et al., 2010). Thus, protein supplementation may balance the ratio energy: protein with metabolic demand of animal and increase energy intake by metabolic control.

Comparing phases

Seasonal variation in protein content of pasture due to changes in physiologic stage of plant, allowed greater CP intake in dry to rainy transition season, when the pasture was in initial stage of growth, followed by rainy season and rainy to dry transition season, when already passed initial stages of growth, and lower CP content in dry season, when plants were in advanced stages of maturity (Table 4).

Although most supplements provided similar DM intake in dry to rainy transition season (phase 3) and rainy season (phase 4), animals that receive energetic supplement (LPHC) had decrease of DM intake in phase 4 in comparison to phase 3 due to decrease in pasture intake. Thus, it was observed that negative effect to energetic supplement on pasture intake was more intense in rainy season than dry to rainy transition season. Carbohydrate supplementation may improves microbial assimilation of nitrogenous compounds in the rumen when there are high availability of N (Souza et al. 2010), thus in situation where forage have high CP content (as dry to rain transition) the negative effects of energetic supplementation on intake and digestibility of pasture are less intense.

The lower pasture intake observed in phase 1 and 2 in all nutritional plans were resulted of distinct process. In suckling phase the calf still is in development and it is less able to utilize rough feed, besides most part of its demand is supplied by milk occurring distinct behavior in intake (Valente et al. 2012b). On other hand, in dry season, the lower intake of pasture is mainly due to insufficient CP intake that may provide ruminal deficiency of nitrogen compounds (Figueiras et al. 2010).

Soluble and potential degradable fractions of carbohydrate and protein, as well effective degradability of DM, NDF and CP are function of season (Ortiz et al. 2010). Similarly, passage rate and DM digestibility are under effect of season (Estrada et al. 2010). However, supplementation may change nutritional behavior along of year. Thus, nutritional plans with low carbohydrate supplements had greater TDN intake in phase 3 than other phases, while most nutritional plans had similar TDN intake between phases 1, 3 and 4. Thus, interactions between supplementary dietetic fractions and basal (pasture) determine ruminal (degradation rate and passage rate) and metabolic (animal physiologic control) on intake and utilization of feed, with distinct effects to same supplement in different seasons.

In long period essay have been observed variations on animal response through seasons with effect of supplementation type (Canesin et al. 2007, Freitas et al. 2011). In this essay were observed effect of season on treatments, fortifying the idea of interaction between supplementation and season on productive response of animals and nutritional characteristics.

Conclusions

Intake of dry matter and TDN are greater in rainy season. Moreover, the effects of supplementation type on nutrition characteristics suffer interaction with season. Supplement with high protein level (supplying 50% CP requirement) increase intake

and digestibility of diet, being more intense when associate with high carbohydrate level (supplying 30% TDN requirement). On other hand, supplement with low protein level (supplying 25% CP requirement) and high carbohydrate level decrease dry matter intake and fiber digestibility, occurring more intense in rainy season.

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Table 1 Composition of supplement

	Nutritional plan ¹				
	Control	HPHC	HPLC	LPHC	LPLC
Corn	-	55.0	0.0	83.5	53.0
Corn gluten	-	3.0	20.0	0.0	14.0
Soybean meal	-	37.0	70.0	12.0	24.0
Urea/ A.S. ²	-	1.0	2.0	0.5	1.0
MM ³	100	4.0	8.0	4.0	8.0

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement. ² Urea + ammonia sulfate (9:1). ³ Mineral mixture; composition: calcium: 8.7 %, phosphor: 9.0 %, sulfur: 9.0 %, sodium: 18.7 %, zinc: 2400.00 mg/kg, copper: 800.00 mg/kg, manganese: 1600.00 mg/kg, iodine: 40.00 mg/kg, cobalt: 8.00 mg/kg, selenium: 8,16 mg/kg.

Table 2 Chemical composition of supplement and pasture

	Supplement ¹				Pasture ²			
	Control	HPHC	HPLC	LPHC	Phase 1	Phase 2	Phase 3	Phase 4
Dry matter	87.1	89.5	85.8	87.0	29.6	42.5	28.0	21.3
Organic matter	89.3	87.4	88.4	85.8	91.4	92.4	92.4	91.5
Crude protein	29.2	55.3	15.4	29.5	8.8	5.5	12.1	10.7
apNDF ³	8.7	10.2	7.4	9.2	65.3	65.0	61.5	61.6
Ether Extract	2.6	1.5	3.0	2.4	1.2	1.2	1.5	1.2
CNF ⁴	46.2	23.3	57.2	43.6	16.1	20.7	17.3	17.9
Lignin ⁵	0.4	0.8	0.2	0.3	4.9	4.4	3.6	2.7

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement.

² Obtained by handle plucked sampling; Phase 1= suckling phase in rainy-dry transition season (112days); Phase 2= post-weaning in dry season (84 days); Phase 3= post-weaning in the dry-rainy transition season (84 days); Phase 4= finishing phase in the rainy season (150 days).

³ Neutral detergent fiber corrected for ash and protein.

⁴ Non-fibrous carbohydrates.

⁵ Corrected for ash.

Table 3 Least square means and standard error (SE) for Intake of supplement, total dry matter (DM), dry matter of pasture (DMP) and total digestible nutrients (TDN)

Nutritional plan	Production phase			
	Phase 1	Phase 2	Phase 3	Phase 4
	Supplement intake (kg)			
Control	-	-	-	-
HPHC	0.734	0.946	0.996	1.758
HPLC	0.344	0.504	0.511	0.771
LPHC	0.671	0.934	0.856	1.768
LPLC	0.353	0.449	0.477	0.793
SE	0.09	0.10	0.12	0.12
	DM			
Control	14.68Bb	13.14Bb	21.63Ba	19.63a
HPHC	17.58Ac	19.30Abc	23.10ABa	20.59ab
HPLC	18.28Ab	16.20Ab	24.78Aa	21.91a
LPHC	17.06ABb	17.50Ab	23.69ABa	19.52b
LPLC	15.66ABc	16.70Abc	23.44ABa	18.87ab
SE	1.00	1.10	1.20	1.40
	DMP			
Control	10.69Aba	13.14b	21.62a	19.63Aa
HPHC	9.53Bc	15.70b	19.9a	15.98Bab
HPLC	12.74Ac	14.30bc	23.01a	19.74Ab
LPHC	9.95Bc	13.96b	20.73a	15.18Bb
LPLC	9.82Bd	14.96c	21.75a	17.93ABb
SE	0.90	0.99	1.05	1.12
	NDF			
Control	7.48ABb	8.87Bb	13.40ABa	11.70ABa
Plan 1	7.01ABc	10.76Aab	12.50Ba	10.05ABb
Plan 2	8.62Ac	9.99ABc	14.70Aa	12.04Ab
Plan 3	6.80Bc	9.98ABb	13.31ABa	9.64Bb
Plan 4	6.90Bc	10.40ABb	13.30ABa	11.28ABab
SE	0.57	0.64	0.67	0.72
	CP			
Control	1.90Cb	0.82Cc	2.95Ba	2.16Bb
HPHC	3.26Aab	2.15Ac	3.60Aa	2.97Ab
HPLC	3.24A2a	1.86Ab	3.54Aa	3.12Aa
LPHC	2.40Bb	1.36Bc	2.87Ba	2.26Bb
LPLC	2.51Bb	1.36Bc	3.21ABa	2.25Bb
SE	0.15	0.16	0.17	0.18
	TDN			
Control	11.04Ba	7.44Cb	12.43Ba	11.41a
HPHC	13.91Aa	11.88Ab	14.99Aa	13.18a
HPLC	13.48ABab	9.85ABc	15.77Aa	13.49b
LPHC	12.11ABab	10.55ABb	14.19ABa	12.05ab
LPLC	11.87Bb	9.69Bc	14.26ABa	12.52ab
SE	0.68	0.76	0.82	0.97

Different subscript lowercase letters within a row denote significant difference according to period ($P < 0.05$) and different subscript capital letters within a column denote significant difference according to nutritional plans ($P < 0.05$).

Table 4 Least square means and standard error (SE) for digestibility of dry matter (DM), neutral detergent fiber corrected for ash and protein (apNDF), crude protein (CP) and perceptual value of total digestible nutrients (TDN)

Nutritional plan	Production phase			
	Phase 1	Phase 2	Phase 3	Phase 4
DM				
Control	66.45Ba	56.69Cb	57.95Db	58.70Cb
HPhC	70.28Aa	62.63Ac	66.37Ab	65.56Ab
HPLC	67.31Ba	61.78Ab	63.59Bb	63.29ABb
LPhC	67.26Ba	62.05Abc	59.00CDc	62.76Bb
LPLC	68.13Ba	59.63Bc	60.37Cc	64.04Ab
SE	0.72	0.79	0.84	0.90
apNDF				
Control	67.52Bb	73.43Aa	72.62BCa	63.86BCc
HPhC	68.34ABb	74.19Aa	75.38Aa	64.41BCc
HPLC	67.86ABc	70.85Bb	74.97ABa	65.38ABd
LPhC	63.96Cc	67.90Cb	70.38Ca	62.79Cc
LPLC	69.62A	69.17BC	70.78C	67.74A
SE	0.69	0.77	0.81	0.87
CP				
Control	71.74Ba	39.58Dd	60.97Cc	67.54Cb
HPhC	78.51Aa	61.78Ad	68.34Ac	74.78Ab
HPLC	77.81Aa	65.71Bc	64.20Bc	70.87BCb
LPhC	71.40Ba	53.01Cc	55.87Dc	68.00BCb
LPLC	74.78Aa	55.74Cc	59.74BCb	71.46ABa
SE	1.05	1.16	1.23	1.31
TDN				
Control	75.39Ba	56.69Bb	59.48Bb	57.98Bb
HPhC	79.62Aa	61.50Ab	64.81Ab	64.04Ab
HPLC	75.64Ba	60.88ABb	63.62ABb	61.65ABb
LPhC	71.00Ca	60.23ABb	59.89Bb	61.42ABb
LPLC	75.60Ba	57.86ABc	60.47Bbc	62.91ABb
SE	1.36	1.50	1.59	1.70

Different subscript lowercase letters within a row denote significant difference according to period ($P < 0.05$) and different subscript capital letters within a column denote significant difference according to nutritional plans ($P < 0.05$).

Tabla 5 Initial body weight and daily weight gain (mean \pm standard error) of animals from the nutritional plans in each phase

Nutritional plan	Production phase			
	Phase 1	Phase 2	Phase 3	Phase 4
Initial body weight (kg)				
Control	138.2 \pm 8.3	209.1 \pm 8.6	219.1 \pm 9.8	251.6 \pm 11.4
HPHC	138.1 \pm 8.5	234.1 \pm 8.7	273.9 \pm 11.0	319.6 \pm 13.0
HPLC	137.3 \pm 7.9	230.1 \pm 9.9	265.4 \pm 10.4	301.5 \pm 11.9
LPHC	138.4 \pm 8.3	234.4 \pm 11.0	264.6 \pm 13.0	306.1 \pm 16.4
LPLC	135.5 \pm 7,2	232.4 \pm 11.3	270.7 \pm 12.0	308.1 \pm 14.6
Daily weight gain (kg/day)				
Control	0.613 \pm 0.03	0.141 \pm 0.01	0.346 \pm 0.03	0.617 \pm 0.05
HPHC	0.817 \pm 0,03	0.503 \pm 0.04	0.458 \pm 0.04	0.796 \pm 0.03
HPLC	0.761 \pm 0.03	0.417 \pm 0.02	0.433 \pm 0.04	0.746 \pm 0.01
LPHC	0.829 \pm 0.03	0.369 \pm 0.04	0.477 \pm 0.03	0.823 \pm 0.06
LPLC	0.816 \pm 0.03	0.358 \pm 0.034	0.424 \pm 0.03	0.813 \pm 0.03

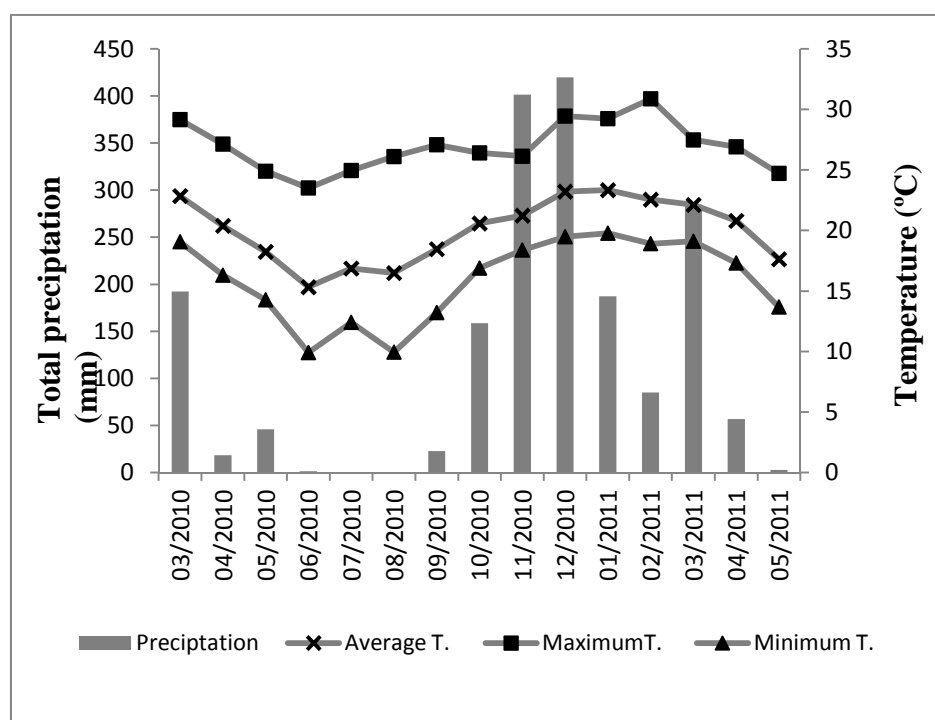


Fig. 1 Precipitation, average temperature (Average T.), maximum temperature (Maximum T.) and minimum temperature (Minimum T.) belong the experimental period.

Grazing behavior and locomotion of young bulls receiving different nutritional plans in tropical pasture

Abstract The objective of this study was to compare visual observation and an electronic grazing time method and to evaluate the effects of nutritional plans in intake, grazing behavior and horizontal and vertical locomotion of young bulls in a tropical pasture. Thirty-nine Nellore young bulls with an average body weight of 345 ± 9.3 kg were used. The experimental treatments consisted of: restricted: animals housed in a plot with a low mass of forage receiving mineral mixture only; control: animals receiving mineral mixture only; HPHC: a high protein and high carbohydrate supplement; HPLC: a high protein and low carbohydrate supplement; LPHC: a low protein and high carbohydrate supplement; LPLC: a low protein and low carbohydrate supplement. GPS Collars equipped with activity sensors were used. Information about head position, latitude, longitude and altitude were recorded. Daytime grazing behavioral patterns monitored by a continuous focal animal recording method was compared to behavior estimated by the activity sensor. Feed intake was measured by a marker method. The Restricted group presented lower ($P < 0.05$) intake of dry matter and TDN. However, differences were not found ($P > 0.05$) between non-supplemented and supplemented animals. Differences were not found ($P > 0.05$) in daytime grazing time obtained by visual observation or the activity sensor method. The restricted group showed longer ($P < 0.05$) grazing times (9.58 hours/day), but differences were not found ($P > 0.05$) in the grazing times between Control (8.35 hours/day) and supplemented animals (8.03 hours/day). The Restricted group presented lower ($P < 0.05$) horizontal locomotion distance (2168 m/day) in comparison to other groups (2580.6 m/day). It can be concluded that the use of activity sensor methods is recommended due to being able to record 24-hours. While supplements with high carbohydrates reduce pasture intake,

they have not changed grazing behavior. Moderate supplementation (until 50% of protein requirement and 30% of energy requirement) of beef cattle on tropical pasture has not effect on daily locomotion.

Keywords: activity, cattle, GPS, sensor, supplement

Implications

Supplementation of grazing beef cattle may affect grazing time, locomotion, nutritional characteristics and may determine animal performance. However, there is little information about these effects, mainly in tropical pastures. Nowadays, a lot of electronic equipment has been developed to use in research, allowing the recovery of information that was impossible or very laborious to obtain before. The Use of electronic equipment may help to develop 24-hour behavioral studies in the pasture. Such information is needed to understand effects of nutrition on the behavior of grazing animals. Supplementation with up to 50% of the protein requirement and 30% of the energy requirement affect total dry matter intake without changing grazing times and locomotion.

Introduction

The use of electronic equipment to monitor cattle grazing has been used to study energy expenditure in physical activities (Brosh et al., 2010) and animal behavior as well as interaction with the environment (Handcock et al., 2009).

Spatial distribution of cattle and pasture utilization are heterogeneous. This heterogeneity may derive from features of the landscape such as topography, forage availability and quality, and also from features of the management system and supplementation (Ungar et al., 2010).

Historically, it has been very difficult to study behavior and the spatial distribution of animals. The measurement of animal behavior through the visual observation method is laborious and presents inherent limitations due to errors associated with the fatigue of the observer, physical obstacles, the effect of proximity of the observer on animals, weather, and daylight. Nowadays, the global positioning system (GPS) is commonly employed in animal research (Trotter et al., 2010). However, the use and integration of this technology is still under development (Handcock et al., 2009).

GPS receivers in a lightweight collar or harness can be deployed for extended periods with little effect on animal behavior. Units derive coordinates from an internal receiver tracking an array of earth-orbiting satellites. Coordinates are stored in onboard memory for later retrieval or relayed to other memory (Johnson and Ganskopp, 2008). Thus it is possible get information of the locomotion (horizontal and vertical) of the animals.

Cattle try to minimize expended energy in grazing activity and maximize energy returns. Therefore, livestock often employ optimization strategies, but ruminants do not always optimize nutrient intake during a meal or on a daily basis (Distel et al., 1995). This occurs because of diet effects (Ganskopp and Bohnert, 2009) and temporal limitations.

Feed intake from cattle grazing is influenced mainly by pasture structure and by supplementation (Baudracco et al., 2010). In addition, supplementation affects forage intake, pasture utilization efficiency (Valente et al., 2011), and animal behavior (Casagrande et al., 2011). However, the intake and utilization of roughage is affected by supplement composition due to associative effects (Souza et al., 2010), which are influenced by the amount of supplement intake (Valente et al., 2011). When cattle receive supplements, reduction of the grazing period may occur (Bargo et al., 2003).

Thus, many studies observed that quantity and composition of supplements affect dry matter intake and grazing behavior though little research has addressed these simultaneous effects.

The objective of this study was to compare visual observation and electronic methods of evaluation of grazing time and to evaluate the effects of nutritional planning on intake, grazing behavior and the horizontal and vertical locomotion of young bulls in a tropical pasture.

Material and methods

Animals, experiment designed and diets

The experimental protocol and procedures were approved by the Universidade Federal de Viçosa Animal Care and Use Committee.

This experiment was carried out at the beef cattle facility of the Universidade Federal de Viçosa, in Viçosa, MG, Brazil (20°45' S 42°52' W). The experimental area is located in a hilly area at an altitude of 670 m with an average slope of 34%.

This study was carried out between January and April, 2011. Throughout the measurement period, the average minimum and maximum temperatures were 19.8° and 29.2°C in January, 18.9° and 30.9°C in February, 19.1° and 27.5°C in March, 17.3° and 26.9°C in April. There were 187 mm of rainfall in January, 85 mm in February, 284 mm in March and 57 mm in April. Animals were submitted to a period of 30 days of adaptation to the diet and handling and a 90-day experimental period for evaluation of intake, movement and behavior.

Thirty-nine Nellore young bulls with an average body weight of 345 ± 9.3 kg S.E. and between the ages of 15 and 17 months were used.

The animals were divided into 6 groups. The Restricted group was composed of four animals housed in a pasture with low forage mass (about 1500 kg DM/ha). The average forage mass of the Restricted group was controlled by using an area ranging from 0.5 to 1 ha. The remaining animals were distributed in two-ha pastures (seven animals/pasture). Five nutritional plans were randomly assigned to animals: Control: mineral mixture only; HPHC: high protein and high carbohydrate supplement; HPLC: high protein and low carbohydrate supplement; LPHC: low protein and high carbohydrate supplement; LPLC: low protein and low carbohydrate supplement (Table 1). About 50 and 25% of the crude protein (CP) requirement were supplied by high and low protein supplements respectively, and about 15 and 30% of the total digestible nutrients (TDN) requirement was supplied by high and low carbohydrate supplement, respectively. Every 28 days, the amount of supplement was adjusted by using the estimated protein and energy requirement by BR-CORTE (Valadares et al., 2006), considering the weight gain in the adaptation period to first adjust of the supplementation and the previous 28 days' weight gain to adjust in the other periods. The animals were fed, in groups, once a day at 1100h. Diet composition is presented in Table 1.

In order to minimize possible effects of paddocks on experimental treatments, the animals were rotated among the five two-ha paddocks every seven days. The pasture was covered by signal grass (*Brachiaria decumbens*).

Behavior and locomotion measurement

GPS collars (GPS_3300LR, Lotek; Ontario, Canada) attached to the neck were used to evaluate grazing behavior (Ungar et al., 2005) and horizontal and vertical locomotion distance (Brosh et al., 2010). Those GPS Collars recorded information about latitude, longitude and altitude.

Horizontal and vertical locomotion distances were computed using Microsoft Excel (Microsoft Corporation) during 10-minute intervals. The time devoted to the horizontal and vertical distances covered was calculated on a daily basis. Animal movements were divided into a horizontal and vertical axis to estimate horizontal locomotion distance and vertical locomotion distance. Positive vertical locomotion was estimated by the total vertical locomotion distance divided by two, due to animals moving half time in downslope and half time in upslope in a delimited area.

The collar contained a head-down activity sensor that consists of a switch that opens or closes according to the head position. The contact closes and the collar registers a down position when the collar is at an angle $>7.5^\circ$ clockwise to perpendicular to the horizontal plane. The contact is open when the collar angle is $>7.5^\circ$ anticlockwise. In the intermediate angle range of $\pm 7.5^\circ$ to perpendicular, the contact could be open or closed. The collar stores the percentage of time the sensor registers the down position during an activity sampling period. The collars were configured to register activity sensor every five minutes.

Three animals from each group were trained to use the GPS collar. After 30 days of adaptation to the collar and handling, two animals (each one from different groups) were monitored with the GPS collar for 48 hours each time. After this period, animals from other groups were monitored in a similar way. Thirty-six 48-hour observations (six measures per group), 10368 GPS records and 20736 activity sensor records were collected between February and April.

The daytime grazing activity pattern was monitored for 6 days (each day in a different week) through continuous focal animal recording method by using binocular with a minimum range of 100 m. Animals were previously trained in the use of the equipment and to the presence of humans, aimed at reducing the effects of human activity on their normal behavior. Evaluation of behavior started at 0600h and finished

at 1800h. Trained personnel observed animal behavior continuously in six hour-shifts and recorded time activities of collar-attached animals. Activities were divided into grazing activities and non-grazing activities which include all regular cattle activities, except grazing, as for example rumination and idle.

To compare visual observation and sensor activity methods, behavior was recorded at the same time visual observations were being carried out, from 0600h to 1800h. Grazing time and other activity times (non-grazing time) were recorded as well.

Experimental procedures and sampling

Forage samples were randomly taken, each 28 days, in order to evaluate the mass of forage per hectare. In each paddock, six forage samples were randomly selected (0.5 x 0.5 m) and cut approximately one cm above the soil. After that, forage subsamples (200 g) were dried at 60°C for 72 hours and ground to pass through a one-mm screen.

Every seven days, a handle plucked sampling was performed simultaneously with the observation of the grazing behavior of the animals in order to obtain samples to evaluate the chemical composition of the forage consumed by the animals. All samples were dried at 60°C for 72 hours, ground to pass through one-mm screen sieve, and proportionally sub-sampled to a composite sample per month.

In order to evaluate forage intake and digestibility, a digestion trial (eight days) was performed in March. Fecal dry matter excretion was obtained by using chromic oxide as an external marker (16 g/day). These portions were packaged in a paper cartridge and directly introduced into the esophagus through a rubber tube. The animals received the marker once daily at 1100h for seven days. After five days of adaptation, fecal samples were collected at 1500h on the sixth day, at 1100h on the seventh day, and at 0700h on the eighth day of the digestion trial period. To evaluate individual

intake of the supplement 16g/day of titanium dioxide was mixed in the supplement and offered to animals in the group. Indigestible neutral detergent fiber (NDF) was used as an internal marker to estimate pasture intake. Fecal samples were dried at 60°C for 72 hours, ground to pass through one-mm screen sieve, and proportionally sub-sampled to a composite sample.

Chemical analysis

Samples of forage, feces and supplement ingredients were analyzed for dry matter (DM, index no. 920.39), nitrogen compounds (N, index no. 954.01), ashes and ether extract (EE, index no. 920.39) as described by AOAC (Association of Official Analytical Chemists, 1990). For analysis of neutral detergent fiber (NDF), samples were treated with thermostable α -amylase without sodium sulfite and corrected for ash residue (Mertens, 2002) and residual nitrogen compounds. The *i*NDF was evaluated using F57 (Ankon[®]) bags and incubated in rumen by 288 (Valente et al., 2011b). Fecal samples were evaluated for chromium content by using atomic absorption methods (Willians et al., 1962).

Mass of forage samples obtained was analyzed for DM, as described before.

The dry matter intake (DMI) was estimated by using the following equation:

$$DMI (kg/day) = \{[(FE \times iNDF_{feces}) - iNDF_{supplement}] / iNDF_{forage}\} + SI,$$

Where: *FE* is the fecal excretion (kg/day); *iNDF feces* is the concentration of *iNDF* in the feces (kg/kg); *iNDF supplement* is the amount of *iNDF* in the supplement (kg); *iNDF forage* is the concentration of NDFi in the forage (kg/kg); and *SI* is the supplement intake (kg).

Statistical analysis

The study was conducted under a completely randomized design using a 2 x 2 + 2 factorial arrangement (two protein amount and two carbohydrate amount plus one control group and one restricted intake group) and comparisons among treatment means were made by using contrasts (Table 2).

Additionally, to verify if the grazing behavior was similar when using visual observation and sensor methods, linear regression was performed to test whether the intercept and slope were equal to zero and one, respectively. Significant difference was considered at $P < 0.05$.

Because of similarities between the methods to estimate grazing behavior, the sensor method was used to evaluate 24-hours grazing behavior.

The data were analyzed using the GLM procedure of SAS version 9.1, (SAS Institute, Inc).

Results

Pasture characteristics and intake

The forage mass in the restricted and other groups were 1.6 and 3.1, 1.7 and 3.5, 1.6 and 3.0, and 1.7 and 2.9 ton/ha of DM in January, February, March and April, respectively.

The forage sampled by handle plucked sampling was considered high quality forage, presenting up to 10.7% of CP (Table 1) which is higher than the level of CP (9%) suggested by Figueiras et al. (2010), that would optimize the forage use by grazing cattle. Although the restricted group presented higher grazing pressure, the CP content was similar to other groups (Table 1).

The animals from the restricted group presented lower ($P<0.05$) intake of DM and total digestible nutrients (TDN). However, differences were not found ($P>0.05$) in the intake of DM and TDN between non-supplemented (Control) and supplemented animals. In addition, differences were not found ($P>0.05$) among supplemented animals in terms of intake of DM and TDN (Table 3). Although differences were not found ($P>0.05$) in the intake of TDN among supplemented animals, nutritional plans with low carbohydrate (HPLC and LPLC) presented greater ($P<0.05$) pasture intake than nutritional plans with high carbohydrate (HPHC and LPHC) (Table 3).

The control animals had greater ($P<0.05$) pasture intake than animals from the restrict group and animals from supplemented groups. The animals that received low carbohydrate levels (HPLC and LPLC) presented greater ($P<0.05$) pasture intake than animals that received high carbohydrate levels (HPHC and LPHC) (Table 3).

Grazing behavior and locomotion

Differences were not found ($P>0.05$) in daytime grazing time obtained by visual observation or activity sensor method. The intercept was not different from zero ($P>0.05$) and the slope was not different from one ($P>0.05$). Moreover, the correlation coefficient between visual observation and activity sensor method was 0.96 (Fig. 1).

Animals from the restricted group presented longer ($P<0.05$) grazing times in a 24-hour-period (40% of the time) than the other groups (34% of the time). In addition, animals from the restricted group presented longer ($P<0.05$) grazing times in a daytime period (0600h to 1800h) than the animals from the control group. However, differences were not found ($P>0.05$) in grazing times in a daytime period among control and supplemented animals and between the nutritional plans (Table 4).

Differences were not found ($P>0.05$) in the grazing time in 0600h-1000h period between the groups. Similarly to the 24-hour grazing time, in the 1000h-1400h period and 0600h-1800h period, grazing times were longer ($P<0.05$) in the restricted group in comparison to other groups. In addition, animals from the restricted group presented longer ($P>0.05$) grazing times than animals from the control group. However, in the 1000h-1400h period and 0600h-1800h period, differences were not found ($P>0.05$) in grazing times between control and supplemented animals and among nutritional plans (Table 4). In daylight (0600h-1800h), about 55.4 and 43% of time were used for grazing in restricted and others groups, respectively.

In the 1400h-1800h period, animals from the restricted group had longer ($P<0.05$) grazing time than the control group and other groups. In the same period, the control animals had longer ($P<0.05$) grazing times than supplemented animals.

The grazing time between 1800h and 0600h (night period) were similar ($P>0.05$) to all groups. The animals from the restricted group presented shorter ($P<0.05$) horizontal locomotion distances (2168 m/day) in comparison to the other groups (2580.6 m/day) (Table 5). However, differences were not found ($P>0.05$) between control and supplemented animals. Similarly, differences were not found ($P>0.05$) among the nutritional plans.

Differences were not found ($P>0.05$) in positive vertical locomotion distances among the groups and presented 363.3 m/day (Table 5). Horizontal and vertical average locomotion speeds during grazing activities were 226.3 and 36.2 m/hour for the restricted group and 318.6 and 45.3 m/hour for other groups, respectively.

Discussion

Intake

The daily pasture intake is a function of grazing time and the rate of forage intake, which is composed by bite rate and bite size. Pasture condition, especially the height, strongly affects the bite size (Hodgson, 1990). Therefore, pasture intake is reduced when forage mass is reduced (Gontijo Neto et al., 2006; Carloto et al., 2011). Some difficulty for apprehension and lower bite mass might occur in the restricted group due to the lower forage mass, which in turn, caused reduction in pasture intake (Table 3).

Forage intake is determined by nutritional and non-nutritional factors. The nutritional factors are related to the nutritional value of forage and metabolic factors; the non-nutritional ones are associated with intake behavior (Carloto et al., 2011). The forage mass and canopy structure may become limiting factors to roughage intake by cattle on pasture (Palhano et al., 2007). Thus, intake is determined by a metabolic requirement, the capacity of the feed to supply nutrients,, the filling capacity of the digestive tract and the effect of time destined to intake activities.

Supplement intake in moderate to high amounts may reduce pasture intake, maintaining or reducing the quantity of total DM intake due to the substitution effect (Valente et al., 2011). The animals that received a high quantity of carbohydrate (HPHC and LPHC) presented lower pasture intake than animals that received a low quantity of carbohydrates (HPLC and LPLC) due to carbohydrate may intensify the substitution effect (Souza et al., 2010). Although the reduction of pasture intake with supplementation has occurred, there was an average increase of 13% in TDN intake.

Grazing Behavior

Visual observation and activity sensor methods presented similar grazing behavior. Therefore, the activity sensor method use is more appropriate because it is less laborious and collect information in daylight and at night.

The time cattle spend eating is directly related to dry matter intake rate. When the forage mass is appropriate, intake rate is high and this reflect in a faster satiety (lower time eating) and greater time of satiety (longer interval between meals).

Animals of the Restrict group presented average grazing time of 9.6 hours/day, longer than eight-nine hours suggested by Hodgson (1990), which may indicate some limitation presented by the canopy to forage intake. The other groups presented average grazing time of 8.2 hours/day, probably, due to the canopy presented higher mass and higher proportion of leaves. Gontijo Neto et al. (2006) found grazing time of 6-10 hours/day with higher grazing time when reduced the forage mass. Excessive grazing time, near to 10 hours/day, indicates that intake is not supplying metabolic requirements and non-nutritional factors are determining the intake. Grazing time is limited by time destined to non-grazing activities, as for example, rumination. Normally, cattle spend 8-11 hours/day grazing, but this may vary in relation to forage mass and canopy structure (Di Marco and Aello 1999). Casagrande et al. (2011) observed that animals spent 30% more time grazing in pasture (*Urochroa brizantha* Marandú) with height of 15 cm than in a pasture with height of 35 cm.

Although the Restrict group had presented longer grazing time in daylight period, all groups presented similar grazing time at night. This indicates that other factors, besides hungry-satiety and pasture characteristics also affect the grazing time and could limited the grazing.

It seems that cattle do not have a preference for grazing in the first hours of the daylight. Cattle usually start grazing after the sunrise. In this study, the animals spent about 1.3 hours grazing in 6a.m.-10a.m. period, evidencing low activity in the early

morning. Casagrande et al. (2011) observed, in tropical conditions, that less than 30% of cattle were grazing before 8a.m., but after 9a.m., 70% of cattle were grazing.

The greatest difference in grazing time was observed in 14p.m.-18p.m. period, due to the mild temperatures. In the hottest period (10a.m.-2p.m.), both supplemented and non-supplemented animals presented short grazing time. At high temperature conditions, it is difficult to lose metabolic heat and occur reduction in DM intake (Neiva et al. 2004; Tucker et al. 2008). In attempt to keep body temperature at an appropriate physiologic level, animals change behavior to reduce the heat production and improve heat lose. In tropical conditions, Titto et al. (2011) found a reduction in grazing in hottest period. However, in attempt to increase the intake of energy and nutrients, animals of the Restrict group presented longer grazing time than the other groups, including at the hottest hours.

The greatest proportion of grazing time (65%) occurred in daylight (Table 4). Thus, factors that affect grazing time are more evidenced in this period. Similarly, Scaglia et al. (2009) observed that 70% of grazing time occurred in daylight.

Supplement intake reduces grazing time (Bremm et al. 2005; Casagrande et al. 2011), but the intensity of the reduction is a function of the amount ingested (Scaglia et al. 2009). Glienke et al. (2010) found lower grazing time for supplemented animals, corresponding to 1% BW of supplement (7.5 hours/day), in comparison with non-supplemented animals (9 hours/day). Nonetheless, in this study, grazing time was not affected by supplementation, possibility because the supplement intake was low.

The supplement type (energy or protein) affects pasture and total DM intake (Souza et al. 2010). Although high carbohydrate supplements reduced pasture intake (Table 3), the total grazing time did not change (Table 4). This corroborated with Casagrande et al. (2011) who found a same grazing time to animals fed energy or

protein supplement (0.3% BW). This occurred due to many factor control feed intake and even grazing time maintenance equal feed intake may change.

Horizontal and Vertical Locomotion

Although of animals of the Restrict group had longer grazing time, they had shorter horizontal locomotion than the other groups (Table 5). This occurred because animals of the Restrict group were located in small plot and plot size affects the walking distance (Brosh et al. 2010).

Plot size may affect grazing behavior (Hunt et al. 2007). In large plots each individual has a wide area to explore and to select forage, but this exploration and selection increase daily activities resulting in longer walked distance which may affect or not the grazing time.

There is a positive correlation between energy expenditure and walking and eating time (Shinde and Karin 2007; Kaufmann et al. 2011) because of the increase of physical activity. Thus, pasture conditions that increase the grazing time and/or locomotion, increase the energy expenditure with physical activity and reduce the energy availability for deposition of tissues.

The energy used for physical activity reduces available energy for production. Sahlu et al. (2004) cited that energy expended with physical activity may be projected based in grazing time, walking time, walked distance, forage quality and land conditions. However, CSIRO (2007) included forage mass. Therefore, the intensity of muscle work is a function of many factors that working together.

Walked distance analyzed alone is not a good index to estimation of energy expenditure. There are variations in physical effort in function of the slope. The coefficient of energy cost to positive vertical locomotion may be as eight times higher than the horizontal locomotion (Brosh et al. 2010).

In a high quality pasture, Brosh et al. (2010) found that total horizontal locomotion distance reached a maximum of 3550 m/day. However, Johnson and Ganskopp (2008) studying cows in large plots, found total horizontal locomotion distance of 7700 m. Daily locomotion distance is very variable and it depends on many factors as for example land conditions, slope, plot size, forage, supplementation and animal.

Aharoni et al. (2009) observed that the speed seldom was higher than 2 km/hour. In agreement, Brosh et al. (2010) found average horizontal locomotion speed of 208 m/hour for grazing and 1813 m/hour for walking, whereas, Baldivieso et al. (2012) found speed of between 150 and 300 m/hour. However, average vertical locomotion speed oscillated between 9.5 and 36 m/hour in the study of Brosh et al. (2010). In this study, average horizontal locomotion speed was 319 m/hour, evidencing that grazing cattle usually move slowly.

Conclusions

Use of activity sensor methods is recommended due to it can record 24-hours data and it is less laborious. In daylight period occurs 65-70% of grazing time.

The type of supplement (relation protein and carbohydrate) do not change total dry matter intake during rainy season. However, supplement with high carbohydrate decreases pasture intake, but does not affect grazing time and locomotion distances. Moderate supplementation (until 50% of protein requirement and 30% of energy requirement) of beef cattle on tropical pasture has not effect on daily locomotion. However, mass of forage and size of plots affect animal locomotion.

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Table 1 Ingredient (as-fed basis) and chemical compositions (% DM basis) of supplements and pastures.

	Nutritional plan ¹						Pasture1 ²	Pasture2 ³
	Restrict	Control	HPHC	HPLC	LPHC	LPLC		
Corn	-	-	55.0	0.0	83.5	53.0		
Corn gluten	-	-	3.0	20.0	0.0	14.0		
Soybean meal	-	-	37.0	70.0	12.0	24.0		
Urea/ A.S. ⁴	-	-	1.0	2.0	0.5	1.0		
MM ⁵	100	100	4.0	8.0	4.0	8.0		
Chemical composition (%)								
Dry matter			87.1	89.5	85.8	87.0	20.5	21.3
Organic matter			89.3	87.4	88.4	85.8	91.9	91.9
Crude protein			29.2	55.3	15.4	29.5	10.6	10.7
NDFap ⁶			8.7	10.2	7.4	9.2	62.7	61.6
Ether extract			2.6	1.5	3.0	2.4	1.2	1.2
NFC ⁷			46.2	23.3	57.2	43.6	17.4	17.9

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC= low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement.

² Obtained by hand plucked sampling to restrict group.

³ Obtained by hand plucked sampling to the other groups

⁴ Urea + ammonia sulfate (9:1).

⁵ Mineral mixture; composition: calcium: 8.7 %, phosphor: 9.0 %, sulfur: 9.0 %, sodium: 18.7 %, zinc: 2400.00 mg/kg, copper: 800.00 mg/kg, manganese: 1600.00 mg/kg, iodine: 40.00 mg/kg, cobalt: 8.00 mg/kg, selenium: 8,16 mg/kg.

⁶Neutral detergent fiber corrected for ash and protein.

⁷ Non-fibrous carbohydrate.

Table 2 Distribution of coefficients for orthogonal contrasts used in the decomposition of the sum of squares

Contrasts ¹	treatments					
	Restrict	Control	HPHC	HPLC	LPHC	LPLC
Orthogonal group						
R	+5	-1	-1	-1	-1	-1
CT	0	+4	-1	-1	-1	-1
P	0	0	+1	+1	-1	-1
C	0	0	+1	-1	+1	-1
PxC	0	0	+1	-1	-1	+1
Additional contrast						
RxCT	+1	-1	0	0	0	0

¹ R= restrict group *versus* other groups, CT= non-supplemented *versus* supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate, RxCT= restrict *versus* control.

Table 3 Least square means and coefficient of variation (CV) for intake of supplement (SI), total dry matter (TDM), pasture (PDM) and of total digestible nutrients (TDN).

	Treatments						CV	P-value ¹					
	Restrict	Control	HPHC	HPLC	LPHC	LPLC		R	CT	P	C	PxC	RxCT
	kg/d												
SI	-	-	1.76	0.77	1.77	0.79	-	-	-	-	-	-	-
	g/kg BW												
TDM	14.8	19.6	20.6	21.9	20.5	20.9	18.4	0.014	0.434	0.722	0.567	0.766	0.077
PDM	17.8	19.6	16.0	19.7	16.0	18.8	19.4	0.129	0.213	0.757	0.024	0.741	0.056
TDN	8.4	11.4	13.2	13.5	12.6	13.2	18.2	0.003	0.111	0.619	0.637	0.898	0.070

¹R= restrict group *versus* other groups, CT= non-supplemented *versus* supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate, RxCT= restrict *versus* control.

Table 4 Least square means and coefficient of variation (CV) for grazing time and other activities time (non-grazing) measured by activities sensor.

Item ²	Treatments							CV(%)	P-value ¹					
	Restrict	Control	HPHC	HPLC	LPHC	LPLC	R		CT	P	C	PxC	RxCT	
G24h	9.58	8.35	7.70	8.45	7.80	8.18	11.7	0.002	0.490	0.821	0.171	0.634	0.037	
O24h	14.43	15.65	16.30	15.55	16.20	15.82	6.2	0.002	0.478	0.852	0.159	0.610	0.039	
G6-10	1.38	1.23	1.27	1.32	1.20	1.56	30.5	0.709	0.583	0.604	0.234	0.365	0.524	
G10-14	2.23	1.42	1.72	1.65	1.80	1.18	32.6	0.009	0.504	0.406	0.145	0.237	0.015	
G14-18	3.08	2.72	2.03	2.42	1.97	2.56	21.7	0.004	0.063	0.865	0.037	0.641	0.243	
G18-6	2.90	3.05	2.70	3.08	2.83	2.86	32.3	0.990	0.677	0.909	0.606	0.653	0.784	
G6-18	6.65	5.30	5.01	5.40	4.95	5.32	15.3	0.001	0.739	0.835	0.289	0.984	0.009	
O6-10	2.62	2.78	2.75	2.68	2.80	2.44	15.0	0.682	0.540	0.570	0.216	0.392	0.479	
O10-14	1.80	2.60	2.32	2.35	2.20	2.82	23.3	0.012	0.481	0.445	0.162	0.208	0.017	
O14-18	0.92	1.28	1.97	1.61	2.05	1.44	34.5	0.004	0.057	0.837	0.040	0.565	0.244	
O18-6	9.12	8.98	9.31	8.93	9.17	9.14	10.3	0.983	0.720	0.943	0.6005	0.653	0.807	
O6-18	5.35	6.70	7.00	6.60	7.07	6.68	12.7	0.001	0.723	0.834	0.267	0.985	0.009	

¹R= restrict group *versus* other groups, CT= non-supplemented *versus* supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate, RxCT= restrict *versus* control.

²G24h= grazing time in 24-hours, O24h= other activities time in 24-hours, G6-10= grazing time between 0600h and 1000h, G10-14= grazing time between 1000h and 1400h, G14-18= grazing time between 1400h and 1800h, G18-6= grazing time between 1800h and 0600h, G6-18= grazing time between 0600h and 18:00h, O6-10= other activities time between 0600h and 1000h, O10-14= other activities time between 1000h and 1400h, O14-18= other activities time between 1400h and 1800h, O18-6= other activities time between 1800h and 0600h, O6-18= other activities time between 0600h and 1800h.

Table 5 Least square means and coefficient of variation (CV) for horizontal (m/day) and positive vertical locomotion (m/day).

	Treatments							CV	P-value ¹					
	Restrict	Control	HPHC	HPLC	LPHC	LPLC	R		CT	P	C	PxC	RxCT	
Horizontal ¹	2168.0	2709.4	2527.9	2438.4	2538.5	2688.9	12.2	0.007	0.307	0.379	0.836	0.418	0.007	
Vertical ²	346.7	381.2	348.3	339.7	373.3	390.4	10.5	0.273	0.360	0.058	0.824	0.504	0.150	

¹R= restrict group *versus* other groups, CT= non-supplemented *versus* supplemented, P = effect of protein amount, C = effect of carbohydrate amount, P*C = effect of interaction of protein and carbohydrate, RxCT= restrict *versus* control.

²Horizontal= Horizontal locomotion.

³Vertical= Positive vertical locomotion.

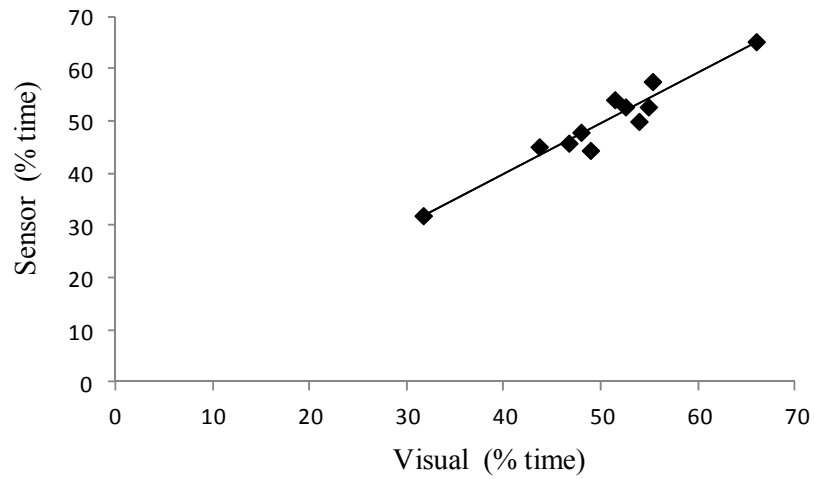


Fig. 1 Percentage of daylight grazing time determined by visual observation and activity sensor. Visual observation values (Xaxis) were compared with the activity sensor values (Y-axis) by linear regression analysis ($Y = 1.3314 + 0.965X$, $R^2 = 0.927$; $r = 0.96$). The intercept was not different from zero ($P > 0.05$) and the slope was not different from one ($P > 0.05$).

Requirement of energy and protein of beef cattle on tropical pasture

Abstract The aim of this essay was estimate protein and energy requirement of beef cattle on tropical pastures from 4 until 18 months. Forty-six beef calves (138.3±3.4 kg of BW and 90-150 days of age) housed in signal grass pasture were used. The animals composed a maintenance group (restricted feeding) or nutritional plan: control = animals received mineral mixture only; HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement. The net energy requirement for weight gain (NE_g) was obtained by linear regression of logarithm of retained energy in function of logarithm of empty body weight gain. The net energy requirement for maintenance (NE_m) was estimated by exponential relation between heat production (kcal/EBW^{0.75}/day) and metabolizable energy intake. The net protein requirement for weight gain (RP) was estimated by multiple linear regression of retained protein in the weight gain of empty body and retained energy. The efficiency of metabolizable energy (ME) for maintenance (k_m) was 0.55 and for weight gain was 0.26. The ME requirement for maintenance was 124 kcal/EBW^{0.75}/day, 11% higher than the requirement for feedlot cattle in Brazil. The RP decreased with increase of body weight. The NE_g and RP may be obtained by equations: RE (Mcal/kg) = 0.044 x EBW^{0.75} x EBWG^{1.1302}, RP (g/day) = -31.45 + 229.69 x EBWG - 8.75 x RE, respectively.

Key-words: nutritional requirement, supplementation, zebu cattle

Introduction

The appropriate feed planning is the base for the development of a modern livestock. Thus, it is necessary knowledge of nutritional value of food and nutritional

demands of animals. However, several factors may affect feed utilization and nutritional demands, being more appropriate to use information from similar production conditions.

Cattle production systems on pasture are marked by their multifactorial and interactive characteristics that besides affect intake and utilization of food, determine the nutritional requirements. The main factors that affect the nutritional demand are the availability and quality of forage (Aharoni et al. 2004), stocking rate (Brosh et al. 2006), supplementation (Scaglia et al. 2009), paddock size (Hunt et al. 2007), slope (Brosh et al. 2010) and weather (Brosh et al. 2006). The CSIRO (2007) describe that under extreme grazing conditions, the energy requirement to maintenance may be increased in about 50%.

In Brazil, as well most tropical region, majority of the cattle slaughters (92%) are produced in pastures (ANUALPEC 2011). However, most of researches to estimate nutritional requirements of beef cattle are conducted in feedlots. Moreover, recent researches had been performed in grazing condition in Brazil (Porto et al. 2012), but due to the complexity and numbers of factors relate to animal response, and the lack of essays in some phases of productive cycle, more essays need to be realized to improve information in this conditions. Thus, this essay aimed estimate protein and energy requirement of beef cattle on tropical pastures from 4 until 18 months.

Material and methods

Animals, experimental design and diets

The experimental protocol and procedures were approved by the Universidade Federal de Viçosa Animal Care and Use Committee.

This experiment was carried out at the beef cattle facility of the Universidade Federal de Viçosa, in Viçosa, MG, Brazil (20°45' S 42°52' W). The experimental area is located in a hilly area at an altitude of 670 m with an average slope of 34%.

This study was carried out between March of 2010 and April of 2011. The weather data are presented in Fig. 1. The calves were submitted to a period of 15 d of adaptation and a 430-d experimental period divided into four phases: phase 1 = suckling phase in rainy-dry transition season (112days); phase 2 = post-weaning in dry season (84 days); phase 3 = post-weaning in the dry-rainy transition season (84 days); phase 4 = fattening phase in the rainy season (150 days).

Forty-six beef calves with average initial body weight of 138.3 ± 3.4 kg and between 90 and 150 days of age and their dams (30 Nellore; 10 $\frac{1}{2}$ Nellore $\frac{1}{2}$ Holstein; 15 $\frac{3}{4}$ Nellore $\frac{1}{4}$ Holstein) were used. Only Nellore sires were used in this study. It was taken randomly five animals in the beginning of the experiment, one calf from each group in the end of the phase 1, one animal from each group in the end of phases 2 and 3, and four in the end of the phase 4 to be slaughtered.

The animals were housed in a 10-ha paddocks of signal grass (*Brachiaria decumbens*) in the phase 1 and in 2.5-ha in the others phases, provided with feeders covered with asbestos tiles and privative feeders for calves (0.5 m per animal) and drinkers. The animals were randomly assigned to 6 groups. The maintenance group was formed only after the weaning with random incorporation of 4 animals from other groups and kept in paddock with low forage mass for the control of the weight gain of the animals in low levels. The forage mass was controlled changing paddock area between 0.5 to 1 ha. The other groups differed by the supplement that received: control = animals received mineral mixture only; HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC = low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate

supplement (Table 1). Approximately 50 and 25% of protein requirement were supplied in high and low protein supplement, respectively, and about 30 and 15% of total digestible nutrients (TDN) requirement was supplied in high and low carbohydrate supplement, respectively. Half of the stipulated requirements were supplied by supplement in phase 1 due to the milk intake in this phase. Every 28 days, the amount of supplement was adjusted by using the estimated protein and energy requirement by BR-CORTE (Valadares et al., 2006), considering the weight gain in the adaptation period to first adjust of the supplementation and the previous 28 days' weight gain to adjust in the other periods.

The supplement composition was formulated for all supplements have similar protein profile with same proportion of protein from each ingredient (Table 2). The animals were supplemented once a day at 11 a.m. In order to minimize possible effects of paddocks on experimental treatments, the animals were rotated among the five pasture paddocks every seven days, allowing each group stay in each paddocks for the same period and intake similar pasture, differing only the supplement intake.

The calves were weaned after the end of the phase 1, when they were about eight months, 112 days after the beginning of experimental period. The animals were weighted in the beginning and in the end of each phase after 16h of fasting.

Experimental procedures and sampling

Every seven days, a handle plucking sample of pasture was taken simultaneously to the observation of grazing behavior of the animals in order to obtain samples to evaluate chemical composition of the forage consumed by the animals. All samples were dried at 60°C for 72 hours, grounded to pass through 1-mm screen sieve and proportionally sub-sampled to a composite sample per period.

In order to evaluate forage intake and digestibility, digestion trial (eight days), was performed simultaneously to the evaluation of performance of the animals in middle of each production phase. Fecal dry matter excretion was determined by using chromic oxide as external marker, 10, 12, 14 and 16 g/day to phases 1, 2, 3 and 4, respectively. These portions were packaged in a paper cartridge and directly introduced into the esophagus through a rubber tube. The animals received the marker once daily at 11 a.m., during seven days of the digestion trial. To evaluate individual intake of supplement 10, 12, 14 and 16 g/day of titanium dioxide were mixed on supplement and offered to the animals in phases 1, 2, 3 and 4, respectively. The forage intake was estimated by using indigestible neutral detergent fiber (iNDF) as internal marker. After five days of adaptation, feces samples were collected at 3 p.m. on the 6th day, at 11 a.m. on the 7th day, and at 7 a.m. on the 8th day of the digestion trial period. The fecal samples were dried at 60 °C for 72 hours, grounded to pass through 1-mm screen sieve, and proportionally sub-sampled to a composite sample by phase.

Milk intake by the calves was estimated on days 28, 56 and 84 of the experimental period (phase 1). Cows were separated from their calves at 6 p.m. At 6 a.m. of the next day, cows were milked immediately after an injection of 2 mL of oxytocin (10 IU/mL; Ocitovet®, Brazil) in the mammary vein and the produced milk was weight. The milking was planned to do not occur time longer than 2 hours from the first and the last cow milked. The exact time when each cow was milked was recorded and the milk production was converted into a 24-hours production. The milk produced was corrected to 4% of fat (4% fat-milk) calculated by the following equation (NRC 2001):

$$4\% \text{ fat-milk (kg)} = 0.4 \times (\text{milk production}) + [15 \times (\text{fat production} \times \text{milk production}/100)]$$

Chemical analysis

The samples of forage, feces and supplement ingredients were analyzed for dry matter (DM, index no. 920.39), crude protein (CP, index no. 954.01), organic matter (OM, index no. 942.05) and ether extract (EE, index no. 920.39) as described by AOAC (Association of Official Analytical Chemists, 1990). Lignin content was obtained by cellulose solubilization in sulfuric acid (Van Soest & Robertson 1985). For analysis of neutral detergent fiber (apNDF) samples were treated with thermostable α -amylase without sodium sulfite and corrected for ash residue (Mertens, 2002) and residual nitrogen compounds (Licitra et al. 1996). The iNDF content was evaluated using F57 (Ankon®) bags incubated in rumen by 288 (Valente et al., 2011b). Fecal samples were evaluated for chromium and titanium dioxide content by using atomic absorption (Willians et al. 1962) and colorimetric (Myers et al., 2004) methods, respectively. Milk was analyzed for protein, fat, lactose and total solids content, using spectroscopy (Foss MilkoScan FT120, Hillerød, Denmark). Content of non-fibrous carbohydrate, corrected for ash and protein (NFCap), was calculated by using the following equation (Detmann & Valadares Filho 2010):

$$\text{NFC} = 100 - [(\% \text{CP} - \% \text{CP urea} + \% \text{ of urea}) + \% \text{apNDF} + \% \text{EE} + \% \text{ash}]$$

The fecal excretion was estimated by ratio of marker dose (chromic oxide) and its concentration in the feces.

The dry matter intake (DMI) was estimated by using the NDFi as an internal marker and calculated by the following equation:

$$\text{DMI (kg/day)} = [((\text{FE} \times \text{iNDF feces}) - \text{iNDF supplement}) \div \text{iNDF forage}] + \text{SI} + \text{MI},$$

Where FE is the fecal excretion (kg/day); iNDF feces is the concentration of iNDF in the feces (kg/kg); iNDF supplement is the iNDF in the supplement (kg); iNDF forage is the concentration of iNDF in forage (kg/kg); SI is the supplement intake and MI is the milk intake.

The estimation of the individual intake of supplement was obtained by using the external marker titanium oxide by using the following equation:

$$SI = (FE \times MCF)/MCS,$$

Where SI is the supplement intake (kg/day); FE is the fecal excretion (kg/day); MCF is the marker concentration in the animal feces (kg/kg); MCS is the marker concentration in the supplement (kg/kg).

The nutrients intake was calculated by total dry matter intake multiplied by their composition (Table 2). Digestible energy (DE) in diet was obtained by the suggested equation by NRC (2000):

$$DE \text{ (Mcal/kg DM)} = 5.6 \times DCP + 9.4 \times DEE + 4.2 \times DNDF + 4.2 \times DNFC$$

Where DCP is the digestible CP; DEE is the digestible EE; DNDF is the digestible NDF and DNFC is the digestible NFC.

Metabolizable energy (ME) was considered as 82% of the DE (NRC, 2000).

Slaughter

The animals were weighted after 16h of fasting. After the reference slaughter (five calves) in the begin of the experimental period, the remaining animals were slaughter in staggered way, being five animals slaughter in the end of phase 1, six animals in the phase 2 and 3, and 24 animals in the phase 4. At slaughter, they were stunned with a captive bolt gun and killed by exsanguination. Weights of the right and left halves of the warm carcass, hide, head, blood, shanks and tail, liver, heart, lung, kidneys, spleen, rumen-reticulum, omasum, abomasum, small intestine, and large intestine as well as internal adipose tissues were recorded after of washed to obtain the empty body weight (EBW). The relation of EBW and the body weight (BW) of animals from reference group was used to estimate the initial EBW of animals that were not slaughter. Organs and viscera were ground in an industrial mill per 1 hour.

After a 24-h chill (4°C), carcass were weighted and right half was subsequently separated into lean tissue, adipose tissue and bone. Half of animals had head and shanks components separated and analyzed and used to estimate the composition of heads and shanks of animals non-sampled. All samples were dried at 55°C for 72-96h. After, samples were pre-degrease (upon extraction with petrol ether in Soxhlet apparatuses for 6h). Then, sample were ground in a ball mill and analyzed.

The body energy was estimate through of protein and energy content and their respective caloric equivalent of 5,6405 and 9,3929 (ARC, 1980). Net energy requirement for weight gain (NEg) for animals with different empty body gain (EBWG) and different EBW was estimated by the following equation:

$$\text{NEg (Mcal/day)} = a \times \text{EBW}^{0.75} \times \text{EBWG}^b$$

Where “a” is the antilog of intercept and “b” is the slope of linear regression of logarithm of retained energy (RE, Mcal/kg of $\text{EBW}^{0.75}$) in function of logarithm of EBWG (kg/day).

Heat production (HP, kcal/ $\text{kg}^{0.75}\text{EBW}$) was calculated as the difference between metabolizable energy intake (MEI, kcal/ $\text{kg}^{0.75}$ EBW) and retained energy (RE, kcal/ $\text{kg}^{0.75}$ EBW). Net energy requirement for maintenance (NEm) was estimated as intercept of exponential relation of HP and the MEI as suggested equation by Valadares Filho et al. (2010):

$$\text{HP} = \beta_0 \times e^{\beta_1 \times \text{MEI}}$$

Where β_0 and β_1 are parameters of the equation.

The metabolizable energy requirement for maintenance (MEM) was calculated by interactive method, assuming that the maintenance requirement is the value which HP is equal to MEI (Lofgreen and Garrett 1968).

The efficiency of EM utilization for maintenance (k_m) was calculated as the NEM divided by the ME of the diet (Garret, 1980). The efficiency of EM utilization for weight gain (k_g) was calculated as the slope of the linear regression of RE in function of the MEI (Ferrel & Jenkins, 1998).

The Net protein requirement for weight gain was calculated as multiple linear regression of retained protein (RP, g/day) in the EBWG (kg/day) and of the RE (Mcal/day) by following equation:

$$RP = \beta_0 + \beta_1 \times EBWG + \beta_2 \times RE$$

Where β_0 , β_1 and β_2 are equation parameters.

Results and discussion

The ratio between EBW and BW found was: $EBW = BW \times 0.881$, close of the 0.891 suggested by the NRC (2000) and a quite higher of 0.863 suggested by the BR-CORTE (Valadares Filho et al., 2010) to grazing cattle. Comparing with individual assays in grazing condition, the value found in this study is a quite lower than values of 0.888, 0.900 and 0.907 found by Moraes et al. (2009), Sales et al. (2009) e Porto et al. (2012), respectively .

The conversion of empty body gain (EBWG) in body weight gain (BWG) was obtained by following equation: $EBWG = 0.880 \times BWG$, the coefficient was lower than 0.951 suggest by NRC (2000). However, cattle from feedlot and pasture have wide differences in diet. Thus, differences in this coefficient between these production system are expect. In grazing conditions, as in this assay, the rumen fill effect caused by rough feed has higher contribution in the weight of the animal than in feedlot conditions. In assays with cattle grazing have been found coefficients lower than suggest by the NRC (2000) and similar to this work, as 0.886 and 0.901 found by Moraes et al. (2009) and Porto et al. (2012), respectively.

The fat deposition rate was higher than the protein deposition rate, evidencing by higher slope of linear regression of logarithm of deposition of body components in function of the logarithm of empty body (Table 3), suggesting change in body composition with increase of body weight (Table 4). The increasing of body weight from 150 kg to 400 kg increased energy and fat in the body in 198 and 258%, respectively. These values were similar to 185 and 215% found by Sales et al. (2009).

The animals were slaughter with 18 months of age in pasture condition without supplementation or with low to moderate supplementation (supplying in the maximum 30% of TDN requirement) through the production cycle, independent of perceptual of fat in body. Thus, the slaughter in early ages plus the low density energy diet occasioned low deposition of fat in carcass, what contributed to the lower energy requirements to weight gain. In addition, they were in growth phase and, therefore, with protein deposition more accelerate than fat deposition, fact that occur normally before of physiology maturate.

The relation between heat production (HP) and metabolizable energy intake (MEI) are showed in Fig. 1, which intercept was 66.86 kcal/EBW^{0.75}/day as requirement of net energy to maintenance (NEm). Using this equation was found the metabolizable energy intake in equilibrium, being the point where HP was equal to the MEI, getting the value of 124 kcal/EBW^{0.75}/day.

In this work was found NEm 7% lower than suggested by the BR-CORTE (Valadares Filho et al. 2010) to grazing condition (71 kcal/EBW^{0.75}/day), which is affected by production condition. In low energy density diet, as in this assay, cattle may develop adaptations in basal metabolism to decrease energy cost of vital function (CSIRO, 2007). However, the most plausible explanation to the NEm low is relate with lower rate of weight gain in compare to feedlot animals, being that gain rate affect the metabolism and the requirement for physiology activities. On other hand, the value of

124 kcal/EBW^{0,75}/day of MEm was similar of value found by the BR-CORTE (Valadares Filho et al. 2010) of 124.7 kcal/EBW^{0,75}/day to Nellore in grazing condition, being 11% higher than animals from same genetic group in feedlot conditions (Valadares Filho et al. 2010). The higher requirement of ME to grazing animals is mainly due to higher energetic expenditure to locomotion and forage intake. However, grazing animals usually intake diets with low energy density and imbalance between energy and protein, occurring lower efficiency in metabolizable energy use (Garret, 1980).

The k_m (NEm/MEm) found in this essay was of 0.55, it was lower than found in feedlot by Chizzotti et al. (2008). However, it was similar to values found by Sales et al. (2009) (0.55) and Porto et al. (2012) (0.58) in grazing conditions. The CSIRO (2007) suggest k_m of 0.62 to animals in low quality diets , being the lower k_m for grazing animals relate with higher physical work to locomotion, selection, apprehension and rumination of feed, and higher imbalance between nutrients and energy then feedlot. However, the conditions of pasture as topography and forage mass and composition may increase the energy expenditure to grazing and affect the k_m (CSIRO 2007).

The regression equation found to describe the relation between the retained energy (RE, Mcal/day) and daily empty body gain (EBWG) in a specific EBW was:

$$RE = 0.044 \times EBW^{0,75} \times EBWG^{1,1302} (R^2 = 0,81).$$

Taking a bull of 400 kg with a gain of 0.75 kg/day and using the equation found in this essay, the energy retained estimated is 2.23 Mcal/day. If the same account is done using the equation from the BR-CORTE (Valadares Filho et al., 2010) to *Bos indicus* bulls on grazing (RE= 0.052 × EBW^{0,75} × EBWG^{1,0962}), the retained energy will be 2.93 Mcal/day, about 23% higher. This difference is due the higher metabolizable energy intake and composition of gain from data of the BR-CORTE (Valadares Filho et al. 2010). In reason of the most part of data from the BR-CORTE (Valadares Filho et al.

2010) be composed by animals in fattening phase, the diet was composed by a higher fraction of grains and the animals had higher fat deposition, having higher energy deposition per weight gain unit, affecting the energy requirement.

The efficiency of energy use to gain (k_g), obtained as the inclination coefficient of the regression of RE in function of MEI to gain was 0.26, close to values of 0.24, 0.25, 0.26 and 0.29 found by Porto et al. (2012), Machado et al. (2012), Moraes et al. (2009) and Sale et al. (2009) obtained in grazing. The BR-CORTE (Valadares Filho et al. 2010) adopted the following equation: $k_g = 0.327 / [(0.539 + (\%RE_p/100)]$, where RE_p is the retained energy as protein. Thus, adopting the RE_p of 48%, which correspond to average value found in this essay, the k_g would be of 0.32, being higher than obtained in this work. However, the equation adopted by the BR-CORTE (Valadares Filho et al. 2010) was developed, mainly, with fattening animals and in feedlot, thus differences with grazing cattle are expected.

A multiple regression of the retained protein (RP, kg/day) in function of the RE (Mcal/day) and of the EBWG (kg/day) was made due the interaction of protein and fat deposition to estimate the net protein requirement (Table 5):

$$RP \text{ (g/dia)} = -31.45 + 229.69 \times EBWG - 8.75 \times RE \text{ (R}^2 = 0,96)$$

Using the equation above obtained the retained protein value or net protein requirement for weight gain (Table 5), occurring decrease of net protein requirement with increase of body weight.

Taking a 300kg Nellore bull with a gain of 0.75 kg, the net protein requirement estimated with equation obtained in this work, is of 116 g/day (Table 5), about 10% lower than suggested by the BR-CORTE (Valadares Filho et al. 2010) (129 g/day) which data include animals of different sexual class and production systems. However, this value was higher than values of 100 and 101 g/day found by Sales et al. (2010) and

Moraes et al. (2010), respectively, and similar to 116 g/day found by Almeida et al. (2009) obtained in grazing conditions.

The body composition changed with increase of weight, occurring increase of fat proportion in body, what may be confirm by higher slope of linear regression of fat deposition in function of body weight than the inclination of linear regression of protein deposition in function of body weight (Table 3). Thus, the lower proportion of protein in the weight gain reflected in lower net protein requirement for body weight gain of animals with higher weight (Table 5).

Conclusions

The metabolizable energy requirement for maintenance of grazing Nellore bulls is 124 kcal/EBW^{0.75}/day. The net energy requirement for bodyweight gain may be obtained by equation: RE (Mcal/kg) = 0.044 x EBW^{0.75} x EBWG^{1.1302}. The efficiency of utilization of metabolizable energy for maintenance (k_m) is of 55% and for weight gain (k_g) is of 26%. In addition, the net protein requirement for weight gain may be obtained by following equation: RP (g/day) = -31.45 + 229.69 x EBWG – 8.75 x RE.

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Table 1 Composition of supplement

	Nutritional plan ¹				
	Control	HPHC	HPLC	LPHC	LPLC
Corn	-	55.0	0.0	83.5	53.0
Corn gluten	-	3.0	20.0	0.0	14.0
Soybean meal	-	37.0	70.0	12.0	24.0
Urea/ A.S. ²	-	1.0	2.0	0.5	1.0
MM ³	100	4.0	8.0	4.0	8.0

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC= low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement.

² Urea + ammonia sulfate (9:1).

³ Mineral mixture; composition: calcium: 8.7 %, phosphor: 9.0 %, sulfur: 9.0 %, sodium: 18.7 %, zinc: 2400.00 mg/kg, copper: 800.00 mg/kg, manganese: 1600.00 mg/kg, iodine: 40.00 mg/kg, cobalt: 8.00 mg/kg, selenium: 8,16 mg/kg.

Table 2 Chemical composition of supplement and pasture

	Supplement ¹				Pasture ²			
	Control	HPHC	HPLC	LPHC	Phase 1	Phase 2	Phase 3	Phase 4
Dry matter	87.1	89.5	85.8	87.0	29.6	42.5	28.0	21.3
Organic matter	89.3	87.4	88.4	85.8	91.4	92.4	92.4	91.5
Crude protein	29.2	55.3	15.4	29.5	8.8	5.5	12.1	10.7
apNDF ³	8.7	10.2	7.4	9.2	65.3	65.0	61.5	61.6
Ether Extract	2.6	1.5	3.0	2.4	1.2	1.2	1.5	1.2
CNF ⁴	46.2	23.3	57.2	43.6	16.1	20.7	17.3	17.9
Lignin ⁵	0.4	0.8	0.2	0.3	4.9	4.4	3.6	2.7

¹ HPHC = high protein and high carbohydrate supplement; HPLC = high protein and low carbohydrate supplement; LPHC= low protein and high carbohydrate supplement; LPLC = low protein and low carbohydrate supplement.

² Obtained by handle plucked sampling; Phase 1= suckling phase in rainy-dry transition season (112days); Phase 2= post-weaning in dry season (84 days); Phase 3= post-weaning in the dry-rainy transition season (84 days); Phase 4= finishing phase in the rainy season (150 days).

³ Neutral detergent fiber corrected for ash and protein.

⁴ Non-fibrous carbohydrates.

⁵ Corrected for ash.

Table 3 Parameters of the linear regression of the logarithm of energy, fat and protein in empty body in function of logarithm of empty body weight

Components	Parameters		
	intercept	slope	R ²
Energy (Mcal)	0.028	1.115	96.87
Fat (kg)	-1.736	1.300	88.23
Protein (kg)	-0.639	0.970	98.85

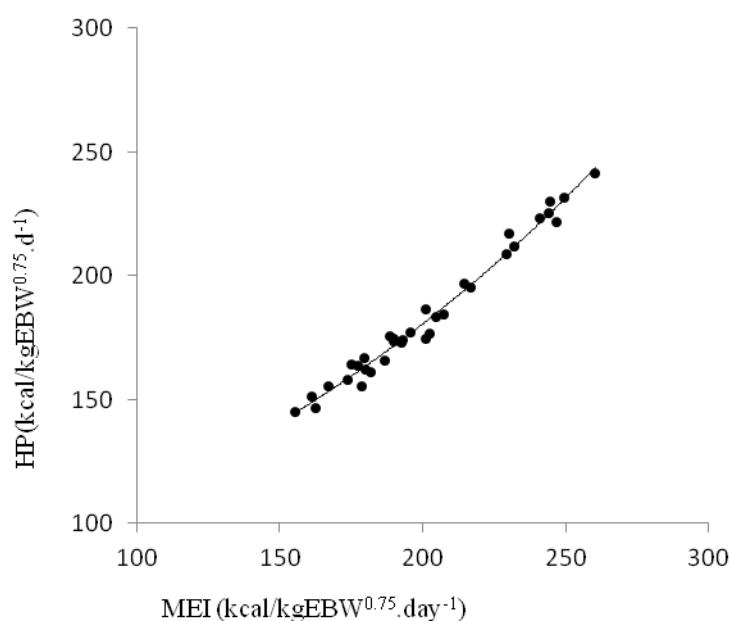
Table 4 Estimated body contents of energy, fat and protein

BW ¹ (kg)	Energy (Mcal)	Fat (kg)	Fat ¹ (g/kg EBW)	Protein (kg)	Protein ¹ (g/kg EBW)
150	246.6	10.5	79.5	26.2	198.3
200	339.8	15.2	86.6	34.6	196.6
250	435.8	20.4	92.6	43.0	195.3
300	534.1	25.8	97.9	51.3	194.2
350	634.2	31.6	102.5	59.6	193.3
400	736.0	37.5	106.7	67.8	192.6
450	839.3	43.8	110.5	76.0	191.9

¹BW = body weight (kg); EBW = empty body weight.

Table 5 Net requirement of protein for weight gain (g/day) of beef cattle of different body weight and weight gains

Weight gain (kg/day)	Body weight (kg/day)						
	150	200	250	300	350	400	450
0.25	33.1	32.2	31.3	30.5	29.6	28.9	28.1
0.50	79.2	77.1	75.2	73.4	71.7	70.0	68.4
0.75	125.0	121.8	118.8	116.0	113.3	110.7	108.1

**Fig. 1** Exponential relation between heat production (HP) and metabolizable energy intake (MEI) ($HP = 66.86 \times e^{0.005MEI}$, $R^2 = 0.98$)

CONCLUSÕES GERAIS

A suplementação afeta o comportamento e o consumo de alimentos de bezerros. De corte em pastejo. Entretanto, não afeta o tempo e frequência de amamentação.

A suplementação eleva o desempenho de tourinhos jovens. No entanto, os planos nutricionais que fornecem baixa quantidade de carboidratos (15% da exigência de NDT) apresentam maior eficiência de uso do suplemento.

O consumo de MS são maiores na época de crescimento das plantas. Entretanto, o efeito do tipo de suplementação sobre os parâmetros nutricionais de animais em pasto tropical sofrem interação da época do ano. Suplementos com alto nível de proteína elevam o consumo e utilização da dieta, sendo o efeito mais intenso quando associado com alto nível de carboidrato (50% das exigências de PB e 30% das exigências de NDT).

A observação visual e método eletrônico apresentam resultados semelhantes. Além disso, a suplementação moderada não altera o comportamento de pastejo.

A exigência de PL_g reduz com aumento do peso corporal. As exigências de energia líquida e proteína líquida para ganho podem ser obtidas pelas equações: ER (Mcal/kg) = $0,044 \times PCVZ^{0,75} \times GPCVZ^{1,1302}$, PR (g/dia) = $-31.45 + 229.69 \times GPCVZ - 8.75 \times ER$, respectivamente.

Apêndices

Tabela 1 Número do animal (n°), tratamento, peso vivo inicial (PVi) e final (PVf), peso de corpo vazio inicial (PCVZi) e final (PCVZf) e dias de pastejo (Dias).

n°	Tratamento	PVi	PVf	PCVZi	PCVZf	Dias
9001	REF	202,5	-	183,2	-	-
9069	REF	123,5	-	116,4	-	-
9071	REF	86,5	-	84,2	-	-
9033	REF	141,5	-	132,3	-	-
9127	REF	79,0	-	80,2	-	-
9013	TMM	163,0	227,5	143,0	202,7	116,0
9019	P3	163,3	262,0	143,2	235,3	116,0
9098	P1	122,0	225,0	107,0	206,9	116,0
9113	P4	101,0	179,0	88,6	161,9	116,0
9115	P2	94,0	151,0	82,4	145,0	116,0
9018	TMM	156,0	225,0	136,8	188,2	207,0
9073	P2	134,0	235,5	117,5	200,3	207,0
9032	P1	171,0	280,0	150,0	239,5	207,0
9006	P3	160,0	250,0	140,3	221,6	207,0
9083	P4	100,0	178,0	87,7	157,8	207,0
9088	P2	145,0	319,5	127,2	277,8	305,0
9039	P3	145,0	302,0	127,2	266,5	305,0
9043	P4	140,0	305,5	122,8	262,3	305,0
9109	P1	105,0	281,0	92,1	234,7	305,0
9128	MAN	80,0	176,0	70,2	151,4	305,0
9079	TMM	104,5	220,0	91,6	194,5	305,0
9058	TMM	155,0	383,0	135,9	324,3	415,0
9050	TMM	151,0	352,5	132,4	302,3	415,0
9041	TMM	144,0	319,5	126,3	279,7	429,0
9092	TMM	111,0	287,5	97,3	240,2	429,0
9027	P1	170,0	497,0	149,1	453,7	429,0
9051	P1	155,0	442,0	135,9	385,6	415,0
9068	P1	122,0	362,5	107,0	326,0	415,0
9116	P1	101,0	390,0	88,6	345,5	429,0
9029	P2	163,0	413,5	143,0	360,2	415,0
9034	P2	161,5	452,0	141,6	393,2	429,0
9094	P2	115,5	368,5	101,3	320,7	415,0
9118	P2	105,5	377,0	92,5	334,8	429,0
9015	P3	166,0	438,0	145,6	393,7	431,0
9070	P3	134,0	410,0	117,5	365,8	417,0
9105	P3	118,5	412,0	103,9	365,1	417,0
9077	P3	120,0	388,0	105,2	353,8	431,0
9096	P4	165,0	499,0	144,7	420,2	431,0
9089	P4	147,0	400,0	128,9	353,1	417,0

Continuação da Tabela 1...

9046	P4	150,5	433,5	132,0	386,9	417,0
9110	P4	100,5	355,0	88,1	318,8	431,0
9044	MAN	150,0	320,0	131,6	261,7	417,0
9004	MAN	146,0	295,5	128,0	241,8	417,0
9086	MAN	115,0	259,0	100,9	220,8	431,0
9119	MAN	111,0	255,0	97,3	216,1	431,0

Tabela 2 Número do animal (n°), tratamento, conteúdo corporal inicial de proteína (PB), extrato etéreo (EE) e energia.

n°	tratamento	PB, kg	EE, kg	Energia, Mcal
9001	REF	37,6	19,3	392,7
9069	REF	24,7	10,5	237,5
9071	REF	17,3	5,3	147,5
9033	REF	26,7	10,3	247,0
9127	REF	15,9	7,0	154,5
9013	TMM	29,5	11,9	446,9
9019	P3	29,6	11,9	521,1
9098	P1	21,9	8,6	470,1
9113	P4	18,0	6,9	336,0
9115	P2	16,7	6,4	265,7
9018	TMM	28,2	11,3	361,4
9073	P2	24,2	9,6	377,8
9032	P1	31,0	12,5	482,0
9006	P3	29,0	11,7	465,1
9083	P4	17,9	6,9	285,0
9088	P2	26,2	10,5	459,9
9039	P3	26,2	10,5	478,9
9043	P4	25,3	10,1	466,2
9109	P1	18,8	7,3	429,9
9128	MAN	14,1	5,3	234,4
9079	TMM	18,7	7,2	344,0
9058	TMM	28,1	11,3	694,1
9050	TMM	27,3	10,9	621,2
9041	TMM	26,0	10,4	609,4
9092	TMM	19,9	7,7	479,4
9027	P1	30,8	12,5	882,8
9051	P1	28,1	11,3	937,9
9068	P1	21,9	8,6	679,8
9116	P1	18,0	6,9	726,7
9029	P2	29,5	11,9	757,1
9034	P2	29,3	11,8	834,4

Continuação da Tabela 2...

9094	P2	20,7	8,1	669,6
9118	P2	18,9	7,3	667,8
9015	P3	30,1	12,1	892,7
9070	P3	24,2	9,6	903,0
9105	P3	21,3	8,3	835,1
9077	P3	21,6	8,5	744,8
9096	P4	29,9	12,1	817,2
9089	P4	26,6	10,6	715,6
9046	P4	27,2	10,9	887,7
9110	P4	17,9	6,9	648,0
9044	MAN	27,1	10,9	485,2
9004	MAN	26,4	10,5	512,7
9086	MAN	20,6	8,1	433,7
9119	MAN	19,9	7,7	406,1
