Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v35i4.21143

Requirement of energy and protein of beef cattle on tropical pasture

Eriton Egidio Lisboa Valente[1*], Mário Fonseca Paulino[2], Edenio Detmann[2], Sebastião de Campos Valadares Filho[2], Javier Enrique Garces Cardenas[2] and Isabela Fernanda Teixeira Dias[2]

*[1]Departamento de Zootecnia, Universidade Estadual do Oeste do Paraná, Rua Pernambuco, 1777, 85960-000, Marechal Cândido Rondon, Paraná, Brazil. [2]Departamento de Zootecnia, Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil. *Author for correspondence. E-mail: eritonvalente@yahoo.com.br*

ABSTRACT. Protein and energy requirements of beef cattle, aged between 4 and 18 months old, on tropical pastures, were estimated. Forty-six Nellore calves (138.3 ± 3.4 kg BW and 90-150 days old), kept on pasture, were distributed in a maintenance group (restricted feeding) or in nutritional plans, receiving a supplements with different amounts of protein and carbohydrate or non-supplemented. The net energy requirement for weight gain (NE_g) was obtained by linear regression of logarithm of retained energy as a function of logarithm of empty body weight gain. The net energy requirement for maintenance (NE_m) was estimated by the exponential relation between heat production and metabolizable energy intake. Net protein requirement for weight gain (RP) was estimated by multiple linear regression of retained protein in the weight gain of empty body (EBWG) and retained energy. The efficiency of metabolizable energy (ME) used for maintenance and for weight gain was 0.55 and 0.26, respectively. The ME requirement for maintenance was 124 kcal $EBW^{-0.75}$. RP decreased in proportion to body weight increase. NE_g and RP may be obtained by equations: RE (Mcal kg^{-1}) = 0.044 x $EBW^{0.75}$ x $EBWG^{1.1302}$ and RP (g day^{-1}) = -31.45 + 229.69 x EBWG – 8.75 x RE, respectively.

Keywords: grazing, Nellore, supplementation.

Exigências de proteína e energia de bovinos de corte em pastagem tropical

RESUMO. Objetivou-se estimar as exigências de proteína e energia de bovinos de corte em pastagens tropicais dos 4 até 18 meses de idade. Foram utilizados 46 bezerros Nelore (138,3 ± 3,4 kg e 90-150 dias de idade) em pastagem, distribuídos em um grupo de mantença (alimentação restrita) ou em planos nutricionais, recebendo suplemento com diferentes quantidades de proteína e carboidrato, ou não suplementados. A exigência de energia líquida para ganho de peso (EL_g) foi obtida por regressão linear do logaritmo da energia retida em função do logaritmo do ganho de peso corporal vazio. A exigência de energia líquida para mantença (EL_m) foi estimada pela relação exponencial entre a produção de calor e consumo de energia metabolizável. A exigência líquida de proteína para ganho de peso (PR) foi estimada pela regressão linear múltipla da proteína retida no ganho de peso de corpo vazio (GPCVZ) e da energia retida. A eficiência de uso da energia metabolizável (EM) para mantença foi de 0,55 e para o ganho de peso foi de 0,26. A exigência de EM para mantença foi de 124 kcal $PCVZ^{-0,75}$. A PR diminuiu com o aumento do peso corporal. O ELg e PR podem ser obtidos por meio das equações: ELg (Mcal kg^{-1}) = 0,044 x $PCVZ^{0,75}$ x $GPCVZ^{1,1302}$, PR (g dia^{-1}) = -31,45 + 229,69 x GPCVZ – 8,75 x ER, respectivamente.

Palavras-chave: pastagem, Nelore, suplementação.

Introduction

Appropriate feed planning for each specific condition foregrounds the development of modern livestock. Knowledge on the nutritional value of food and the nutritional demands of animals are thus required. Since several factors may affect feed utilization and nutritional demands, it is more appropriate to use information from similar production conditions.

Cattle production systems on pasture are marked by their multifactorial and interactive characteristics which not only affect intake and utilization of food but also determine nutritional requirements. The main factors that affect nutritional demands are forage availability and quality (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). CSIRO (2007) reports that under extreme grazing conditions the energy requirement for maintenance may be increased by about 50%.

In Brazil and in many tropical regions, most slaughtered cattle (about 92%) are produced in pastures (ANUALPEC, 2013). As a rule, research to estimate nutritional requirements of beef cattle is conducted in feedlots. However, recent researches have been performed in grazing conditions (PORTO et al., 2012), although, due to the complexity and numerous factors related to animal response and due to the lack of assays on some phases of productive cycle, further investigation must be performed to improve information for such conditions. Current assay estimates protein and energy requirement of 4-18-month-old beef cattle on tropical pastures.

Material and methods

Animals, experimental design and diets

The experimental protocol and procedures were approved by the Animal Care Committee of the Federal University of Viçosa, Viçosa Minas Gerais State, Brazil, and the experiment was performed at the beef cattle facility of the Universidade Federal de Viçosa, Viçosa Minas Gerais State, Brazil (20º45' S; 42º52' W). The experimental area is located on a hilly area at an altitude of 670 m with an average slope of 34%.

Current study was carried out from March 2010 to April 2011. Figure 1 provides climatic data. The calves were adapted during a period of 15 days and the 430-day experimental period was divided into four phases: Phase 1 = suckling phase in the rainy-dry transition season (112 days); Phase 2 = post-weaning in the 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).

The experiment comprised forty-six Nellore calves with average initial body weight 138.3 ± 3.4 kg and between 90 and 150 days old and their dams. Five animals were randomly retrieved at the start of the experiment, or rather, one calf from each group at the end of Phases 1, 2 and 3, and four at the end of Phase 4 for slaughter.

The animals were housed in 10-ha paddocks of signal grass (*Brachiaria decumbens)* during Phase 1 and in 2.5-ha paddocks in the other phases. Pens were provided with drinking troughs and with individual feeders for calves (0.5 m per animal) and regular feeders for the other animals. The animals were randomly assigned to 6 groups. The maintenance group was formed only after weaning, with the random incorporation of 4 animals from other groups. They were kept in paddocks with low forage mass to provide weight gain at low levels (0.10 to 0.15 kg day^{-1}). Forage mass was controlled by varying between 0.5 and 1 ha the paddock area, with the same number of animals (changing stocking rate). The other groups differed by the supplement 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 digestible energy (DE) 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 during this phase. Supplement amount was adjusted every 28 days according to the protein and energy requirement estimated by BR-Corte (VALADARES FILHO et al., 2006), taking into consideration weight gain during the adaptation period for the first adjustment and for the 28 days previous to the adjustment during the other periods.

Table 1. Composition of supplement.

	Nutrition 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 %, phosphorus: 9.0 %, sulfur: 9.0 %, sodium: 18.7 %, zinc: 2400.00 mg kg^{-1}, copper: 800.00 mg kg^{-1}, manganese: 1600.00 mg kg^{-1}, iodine: 40.00 mg kg^{-1}, cobalt: 8.00 mg kg^{-1}, selenium: 8.16 mg kg^{-1}.

The supplement composition was formulated so that all supplements could have a similar protein profile, with the same protein proportion from each ingredient (Table 2). Calves were supplemented once a day at 11:00 hours. 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 to stay in each paddock for the same period and intake similar pasture. Difference consisted only in the supplement intake.

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

[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; Phase 1= suckling phase in rainy-dry transition season (112 days); 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.

Calves were weaned after the end of Phase 1, approximately when eight months old, 112 days after the beginning of the experimental period. The animals were weighed in the beginning and at the end of each phase, after 16 hours fasting.

Experimental procedures and sampling

Simultaneously to the observation of the animals´ grazing behavior, a hand-plucked sample of pasture was retrieved every seven days to evaluate the chemical composition of the forage consumed by the animals. All samples were dried at 60ºC for 72 hours, ground for 1-mm screen sieve and proportionally sub-sampled to a composite sample per period.

So that forage intake and digestibility could be evaluated, a digestion trial (eight days) was performed, simultaneously to the evaluation of the animals´ performance, in the middle of each production phase. Fecal dry matter excretion was determined by chromic oxide as external marker, with 10, 12, 14 and 16 g day^{-1}, respectively for phases 1, 2, 3 and 4. The portions were packed in a paper cartridge and directly introduced into the esophagus through a rubber tube. The animals received the marker once a day at 11:00 hours during the seven first days of the digestion trial. Further, 10, 12, 14 and 16 g day^{-1} of titanium dioxide were mixed with the supplement and offered to the animals in Phases 1, 2, 3 and 4, respectively, to evaluate individual intake of supplement. Forage intake was estimated by indigestible neutral detergent fiber (iNDF) as internal marker. After five days of adaptation, feces samples were collected at 15:00 hours on the 6th day; at 11:00 hours on the 7th day; at 07:00 on the 8th day of the digestion trial period. Fecal samples were dried at 60ºC for 72 hours, ground for 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 18:00 hours. At 06:00 next day, the cows were milked immediately after injecting 2 mL of oxytocin (10 IU mL^{-1}; Ocitovet®, Brazil) in the mammary vein and the produced milk was weighed. The milking was planned so that it did not take longer than 2 hours from the first to the last cow. 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% fat (4% fat-milk) calculated by equation (NRC, 2001): 4% fat-milk (kg) = 0.4 x (milk production) + [15 x (fat production x milk production 100^{-1}).

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 (1999). 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) to analyze the neutral detergent fiber (apNDF). The iNDF content was evaluated by F57 (Ankom®) bags incubated in rumen by 288 (VALENTE et al., 2011). Fecal samples were evaluated for chromium and titanium dioxide contents respectively by atomic absorption (WILLIAMS et al., 1962) and colorimetric (MYERS et al., 2004) methods. Milk was analyzed for protein, fat, lactose and total solids by spectroscopy (Foss MilkoScan FT120, Hillerød, Denmark). Contents of non-fibrous carbohydrate (NFC) were calculated by the equation (DETMANN; VALADARES FILHO, 2010):

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

Fecal excretion was estimated by marker dose ratio (chromic oxide) and its concentration in the feces. Dry matter intake (DMI) was estimated by NDFi as an internal marker and calculated by the equation:

$$DMI (kg\ day^{-1}) = [((FE \times iNDF\ feces) - iNDFsupplement) \div iNDF\ forage] + SI + MI$$

where:

FE is the fecal excretion (kg day^{-1});

iNDF feces is the concentration of iNDF in the feces (kg kg^{-1});

iNDFsupplement is the iNDF in the supplement (kg);

iNDF forage is the concentration of iNDF in forage (kg kg^{-1});

SI is the supplement intake;

MI is the milk intake.

Individual intake of supplement was estimated by using the external marker titanium oxide in the equation:

$$SI = (FE \times MCF)\, MCS^{-1}$$

where:

SI is the supplement intake (kg day^{-1});

FE is the fecal excretion (kg day^{-1});

MCF is the marker concentration in the animal feces (kg kg^{-1});

MCS is the marker concentration in the supplement (kg kg^{-1}).

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

$$DE\ (Mcal\ kg^{-1}\ DM) = 5.6 \times DCP + 9.4 \times DEE + 4.2 \times DNDF + 4.2 \times DNFC$$

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 82% of DE (NRC, 2000).

Slaughter

The animals were weighted after 16 hours fasting. After slaughter (five calves) at the beginning of the experimental period, the remaining animals were slaughter at different phases: five animals were slaughtered at the end of Phase 1; six animals in Phases 2 and 3; 24 animals in Phase 4. Slaughter process comprised stunning with a bolt gun and subsequent exsanguination. 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 and large intestine and internal adipose tissues were weighed and recorded after washing to obtain the empty body weight (EBW). The relationship between EBW and body weight (BW) of animals from the reference group was used to estimate the initial EBW of animals that were not slaughter. Organs and viscera were ground in an industrial mill for 1 hour.

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

The body energy was estimated by 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 equation:

$$NEg\ (Mcal\ day^{-1}) = a \times EBW^{0.75} \times EBWG^{b}$$

where:

'a' is the antilog of intercept and 'b' is the slope of linear regression of logarithm of retained energy (RE, Mcal kg^{-1} of $EBW^{0.75}$) as a function of the logarithm of EBWG (kg day^{-1}).

Heat production (HP, kcal.$kg^{-0.75}$ EBW^{-1}) is the difference between metabolizable energy intake (MEI, kcal.$kg^{-0.75}$ EBW^{-1}) and retained energy (RE, kcal $kg^{-0.75}$ EBW^{-1}). Net energy requirement for maintenance (NE_m) was estimated as an intercept of the exponential relation of HP and MEI by the equation suggested by Valadares Filho et al. (2010):

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

where:

β_0 and β_1 are parameters of the equation.

The metabolizable energy requirement for maintenance (ME_m) was calculated by the interactive method, assuming that the maintenance requirement was the rate by which HP was equal to MEI (LOFGREEN; GARRETT, 1968).

The efficiency of EM for maintenance (k_m) was calculated by NE_m divided by ME of the diet (GARRETT, 1980). The efficiency of EM for weight gain (k_g) was calculated as the slope of the linear regression of RE as a function of MEI (FERRELL; JENKINS, 1998).

The net protein requirement for weight gain was calculated as the multiple linear regression of retained protein (RP, g day^{-1}) in EBWG (kg day^{-1}) and of RE (Mcal day^{-1}), by 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 x 0.881, close to 0.891 suggested by NRC (2000) and somewhat higher than 0.863 suggested by the BR-Corte (VALADARES FILHO et al., 2010) for grazing cattle. When rates in individual assays in grazing condition were compared, the rate in current study was quite lower than rates 0.888, 0.900 and 0.907 found by Moraes et al. (2009), Sales et al. (2009) and Porto et al. (2012), respectively.

The conversion of empty body gain (EBWG) into body weight gain (BWG) was obtained by the following equation: EBWG = 0.880 x BWG and the coefficient found was lower than 0.951 suggested by NRC (2000). However, cattle from feedlot and pasture have wide differences in diet. In fact, differences in this coefficient between the production systems were expected. As may be observed in current assay, in grazing conditions, the rumen fill effect caused by rough feed had a higher contribution in the animal´s weight than that in feedlot conditions. In assays with grazing cattle, coefficients have been found lower than those suggested by NRC (2000) and similar to current work, or rather, 0.886 and 0.901 reported by Moraes et al. (2009) and Porto et al. (2012), respectively.

The fat deposition rate was higher than the protein deposition rate. The above was evidenced by a higher slope of linear regression of logarithm of deposition of body components as a function of the logarithm of empty body (Table 3) which suggested change in body composition with increase of body weight (Table 4). Increase in body weight from 150 kg to 400 kg caused an increase in energy and fat in the body by 198 and 258%, respectively. These rates were similar to 185 and 215% reported by Sales et al. (2009).

Table 3. Parameters of the linear regression of energy, fat and protein logarithm in empty body as a 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

The animals were slaughter at the age of 18 months in pasture condition without supplementation or with low to moderate supplementation (supplying maximum 30% of DE requirement) according to the production cycle, regardless of body fat. Slaughter at an early age coupled to low density energy diet caused low fat deposition in the carcass, which contributed towards lower energy requirements to weight gain. In addition, the animals were in the growth phase and therefore with a more accelerated protein deposition than fat deposition. The above normally occurs prior to physiological maturity.

Table 4. Estimated body contents of energy, fat and protein.

BW[1] (kg)	Energy (Mcal)	Fat (kg)	Fat[1] ($g\ kg^{-1}$ EBW)	Protein (kg)	Protein[1] ($g\ kg^{-1}$ 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

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

The relation between heat production (HP) and metabolizable energy intake (MEI) are shown in Figure 1, with an intercept of 66.86 kcal $EBW^{-0.75}$ day^{-1} as requirement of net energy for maintenance (NE_m). The equation demonstrated the metabolizable energy intake in equilibrium, when HP was equal to MEI, at the rate of 124 kcal $EBW^{-0.75}$ day^{-1}.

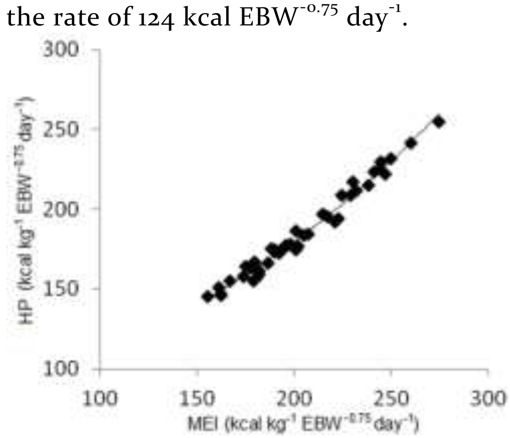

Figure 1. Exponential relationship between heat production (HP) and metabolizable energy intake (MEI) ($HP = 66.86 \times e^{0.005MEI}$; R^2 = 0.98).

Current assays showed that NE_m was 7% lower than rate suggested by BR-CORTE (VALADARES FILHO et al., 2010) for grazing condition (71 kcal $EBW^{-0,75}$ day^{-1}), influenced by production conditions. Similar to current assay, cattle in low energy density diet may develop adaptations in basal metabolism to decrease energy cost of vital function (CSIRO, 2007). However, the most plausible explanation to low NE_m was related to a lower rate of weight gain when compared to that with feedlot animals. Gain rate actually affected the metabolism and the requirement for physiology activities. On the other hand, the rate of 124 kcal $EBW^{-0.75}$ day^{-1} for ME_m was similar to the rate recommended by BR-Corte (VALADARES FILHO et al., 2010), or rather, 124.7 kcal $EBW^{-0.75}$ day^{-1} for Nellore in grazing condition which was 11% higher than that in animals from same genetic group in feedlot conditions (VALADARES FILHO et al., 2010). Higher ME requirements for grazing animals was mainly due to higher energetic expenditure for locomotion and forage intake. However, grazing animals usually intake diets with low energy density and imbalance between energy and protein, with lower efficiency in the use of metabolizable energy (GARRETT, 1980).

The k_m (NE_m / ME_m) found in current assay was 0.55, which was lower than that reported in feedlots by Chizzotti et al. (2008), but similar to rates found by Sales et al. (2009) (0.55) and Porto et al. (2012) (0.58) in grazing conditions. CSIRO (2007) suggested k_m = 0.62 for animals with low quality diets, or rather, a lower k_m for grazing than that in feedlot and related to higher physical work in locomotion, selection, apprehension and rumination of feed, and to higher imbalance between nutrients and energy than that occurring in feedlots. However, grazing conditions, such as topography and forage mass and composition, may increase energy expenditure in grazing and thus affect k_m (CSIRO, 2007). Therefore, a decrease of k_m was expected due to the hilly topographic conditions in which current assay was conducted.

Regression equation which described the relation between the retained energy (RE, Mcal day^{-1}) 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).

In the case of a 400 kg bull with a weight gain of 0.75 kg day^{-1}, the estimated energy retained was 2.23 Mcal day^{-1}, by the above equation. If the same procedure was done by the equation recommended by BR-CORTE (VALADARES FILHO et al., 2010) to *Bos indicus* bulls in grazing conditions ($RE = 0.052 \times EBW^{0,75} \times EBWG^{1,0962}$), the retained energy would be 2.93 Mcal day^{-1}, or rather, approximately 23% higher. This difference was due to higher metabolizable energy intake and composition of gain from BR-CORTE data (VALADARES FILHO et al., 2010). This was due to the fact that most data from BR-CORTE (VALADARES FILHO et al., 2010) was retrieved from data of animals in the fatting phase. In fact, diet was composed by higher grain fraction and the animals had higher fat deposition and higher energy deposition per weight gain unit, which affected energy requirements.

The efficiency of energy use for gain (k_g), obtained as the inclination coefficient of the regression of RE as a function of MEI for gain, was 0.26, close to the rates 0.24, 0.25, 0.26 and 0.29 respectively found by Porto et al. (2012), Machado et al. (2012), Moraes et al. (2009) and Sales et al.(2009) for grazing. BR-CORTE (VALADARES FILHO et al., 2010) adopted the following equation:

$$kg = 0.327\ [(0.539 + (\%REp\ 100^{-1})]^{-1}$$

where:

RE_p is the retained energy as protein.

Thus, when RE_p = 48%, which corresponded to average rate found in current essay, the k_g would be 0.32, or rather, higher than that in current assay. In fact, the equation adopted by BR-CORTE (VALADARES FILHO et al., 2010) was mainly developed with fatting animals and in feedlot, and thus the above different rates from those in grazing cattle were expected.

A multiple regression of the retained protein (RP, kg day^{-1}) as a function of RE (Mcal day^{-1}) and of EBWG (kg day^{-1}) was due to the interaction of protein and fat deposition to estimate net protein requirements (Table 5): RP (g day^{-1}) = – 31.45 + 229.69 × EBWG – 8.75 × RE (R^2 = 0.96).

Retained protein rates or net protein requirements for weight gain were thus obtained from the above equation (Table 5), with a decrease in net protein requirements with an increase in body weight.

Table 5. Net requirement of protein for weight gain (g day^{-1}) of beef cattle of different body weight and weight gains.

Weight gain (kg day^{-1})	Body weight (kg day^{-1})						
	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

In the case of a 300 kg Nellore bull with a weight gain of 0.75 kg, the net protein requirements estimated by the above equation were 116 g day^{-1}

(Table 5), or rather, approximately 10% lower than the percentage suggested by BR-CORTE (VALADARES FILHO et al., 2010) (129 g day^{-1}), with data which included animals of different sexual class and production systems. However, this rate was higher than rates 100 and 101 g day^{-1} found by Sales et al. (2010) and Moraes et al. (2010), respectively, and similar to 116 g day^{-1} reported by Almeida et al. (2009) obtained in grazing conditions.

The body composition changed with weight increase due to an increase in fat proportion in the body. This fact may be confirmed by a higher slope of linear regression of fat deposition as a function of body weight than the inclination of linear regression of protein deposition as a function of body weight (Table 3). Thus, lower protein proportions in weight gain reflected a lower net protein requirement for body weight gain of animals with higher weight (Table 5).

Conclusion

Metabolizable energy requirement for the maintenance of grazing Nellore bulls is 124 kcal $EBW^{-0.75}$ day^{-1}. The net energy requirement for bodyweight gain may be obtained by equation: RE (Mcal kg^{-1}) = 0.044 x $EBW^{0.75}$ x $EBWG^{1.1302}$. Efficiency of metabolizable energy for maintenance (k_m) and weight gain (k_g) is 55% and 26%, respectively. Further, net protein requirement for weight gain may be obtained by the equation: RP (g day^{-1}) = -31.45 + 229.69 x EBWG – 8.75 x RE.

References

ALMEIDA, V. V. S.; QUEIROZ, A. C.; SILVA, R. R.; SILVA, F. F.; OLIVEIRA, A. C.; SANTANA JÚNIOR, H. A. Body composition and net and dietary macrominerals requirements of Nellore steers under grazing. **Revista Brasileira de Zootecnia**, v. 38, n. 6, p. 1081-1087, 2009.

AHARONI, Y.; BROSH, A.; ORLOV, A.; SHARGAL, E.; GUTMAN, M. Measurements of energy balance of grazing beef cows on Mediterranean pasture, the effects of stocking rate and season: 1. Digesta kinetics, faecal output and digestible dry matter intake. **Livestock Production Science**, v. 90, n. 2-3, p. 89-100, 2004.

ARC-Agricultural Research Council. **The nutrient requirements of ruminants livestock**. London: Commonwealth Agricultural Bureaux, 1980.

ANUALPEC-Anuário da Pecuária Brasileira. São Paulo: Instituto FNP, 2013.

AOAC-Association of Official Analytical Chemists. **Official methods of analysis**. 16th ed. Washington, D.C.: AOAC International, 1999.

BROSH, A.; HENKIN, Z.; UNGAR, E. D.; DOLEV, A.; ORLOV, A.; YEHUDA, Y.; AHARONI, Y. Energy cost of cows' grazing activity: the use of heart rate GPS methods for direct field estimation. **Journal of Animal Science**, v. 84, n. 7, p. 1951-1967, 2006.

BROSH, A.; HENKIN, Z.; UNGAR, E. D.; DOLEV, A.; SHABTAY, A.; ORLOV, A.; YEHUDA, Y.; AHARONI, Y. Energy cost of activities and locomotion of grazing cows: a repeated study in larger plots. **Journal of Animal Science**, v. 88, n. 1, p. 315-323, 2010.

CHIZZOTTI, M. L.; TEDESCHI, L. O.; VALADARES FILHO, S. C. A meta-analysis of energy and protein requirements for maintenance and growth of Nellore cattle. **Journal of Animal Science**, v. 86, n. 8, p. 1588-1597, 2008.

CSIRO-Commonwealth Scientific and Industrial Research Organization. **Nutrients requirements of domesticated animals ruminants**. Victoria: Australian Agricultural Council, 2007.

DETMANN, E.; VALADARES FILHO, S. C. On the estimation of non-fibrous carbohydrates in feeds and diets. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 62, n. 4, p. 980-984, 2010.

FERRELL, C. L.; JENKINS, T. G. Body composition and energy utilization by steers of diverse genotypes fed a high-concentrate diet during the finishing period: II. Angus, Boran, Brahman, Hereford, and Tuli sires. **Journal of Animal Science**, v. 76, n. 2, p. 647-657, 1998.

GARRETT, W. N. Factors influencing energetic efficiency of beef production. **Journal of Animal Science**, v. 51, n. 6, p. 1434-1440, 1980.

HUNT, L. P.; PETTY, S.; COWLEY, R.; FISHER, A.; ASH, A. J.; MACDONALD, N. Factors affecting the management of cattle grazing distribution in northern Australia: preliminary observations on the effect of paddock size and water points. **Rangeland Journal**, v. 29, n. 2, p. 169-179, 2007.

LICITRA, G.; HERNANDEZ, T. M.; VAN SOEST, P. J. Standardization of procedures for nitrogen fractionation of ruminant feeds. **Animal Feed Science and Technology**, v. 57, n. 4, p. 347-358, 1996.

LOFGREEN, G. P.; GARRETT, W. N. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. **Journal of Animal Science**, v. 27, n. 3, p. 793-806, 1968.

MACHADO, P. A. S.; VALADARES FILHO, S. C.; VALADARES, R. F. D.; PAULINO, M. F.; PAULINO, P. V. R.; MARCONDES, M. I. Desempenho e exigências de energia e proteína de bovinos de corte em pasto suplementados. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 64, n. 3, p. 683-692, 2012.

MERTENS, D. R. Gravimetric determination of amylase treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. **Journal of AOAC International**, v. 85; n. 6, p. 1212-1240, 2002.

MORAES, E. H. B. K.; PAULINO, M. F.; MORAES, K. A.

K.; FIGUEIREDO, D. M.; VALADARES FILHO, S. C.; PAULINO, P. V. R.; COUTO, V. R. M. Exigências de energia de bovinos de corte em pastejo. **Revista Brasileira de Zootecnia**, v. 38, n. 5, p. 933-940, 2009.

MORAES, E. H. B. K.; PAULINO, M. F.; MORAES, K. A. K.; VALADARES FILHO, S. C.; FIGUEIREDO, D. M.; COUTO, V. R. M. Exigências de proteína de bovinos anelorados em pastejo. **Revista Brasileira de Zootecnia**, v. 39, n. 3, p. 601-607, 2010.

MYERS, W. D.; LUDDEN, P. A.; NAYIGIHUGU, V.; HESS, B. W. Technical note: a procedure for preparation and quantitative analysis of samples for titanium dioxide. **Journal of Animal Science**, v. 82, n.1, p. 179-193, 2004.

NRC-National Research Council. **Nutrient requirements of beef cattle**. Washington, D.C.: National Academic Press, 2000.

NRC-National Research Council. **Nutrient requirements of dairy cattle**. 7th ed. Washington, D.C.: National Academic Press, 2001.

PORTO, M. O.; PAULINO, M. F.; VALADARES FILHO, S. C.; DETMANN, E.; CAVALI, J.; SALES, M. F. L.; VALENTE, E. E. L.; COUTO, V. R. M. Nutritional requirements of energy, protein and macrominerals for maintenance and weight gain of young crossbred Nellore × Holstein bulls on pasture. **Revista Brasileira de Zootecnia**, v. 41, n. 3, p. 734-745, 2012.

SALES, M. F. L.; PAULINO, M. F.; VALADARES FILHO, S. C.; PAULINO, P. V. R.; PORTO, M. O.; COUTO, V. R. M. Composição corporal e requisitos energéticos de bovinos de corte sob suplementação em pastejo. **Revista Brasileira de Zootecnia**, v. 38, n. 7, p. 1355-1362, 2009.

SALES, M. F. L.; PAULINO, M. F.; VALADARES FILHO, S. C.; CHIZZOTTI, M. L.; BARROS, L. V. B.; PORTO, M. O. Exigências protéicas de bovinos de corte suplementados a pasto. **Revista Brasileira de Zootecnia**, v. 39, n. 9, p. 2066-2072, 2010.

SCAGLIA, G.; BOLAND, H. T.; WYATT, W. E. E. Effects of time of supplementation on beef stocker calves grazing ryegrass. II. Grazing behavior and dry matter intake. **The Professional Animal Scientist**, v. 25, n. 6, p. 749-756, 2009.

VALADARES FILHO, S. C.; PAULINO, P. V. R.; MAGALHÃES, K. A. **Exigências nutricionais de zebuínos e tabelas de composição de alimentos**: BR-Corte. Viçosa: UFV, 2006.

VALADARES FILHO, S. C.; MARCONDES, M. I.; CHIZZOTTI, M. L.; PAULINO, P. V. R. **Exigências nutricionais de zebuínos puros e cruzados**: BR-Corte. 2. ed. Viçosa: UFV, 2010.

VALENTE, T. N. P.; DETMANN, E.; QUEIROZ, A. C.; VALADARES FILHO, S. C.; GOMES, D. I.; FIGUEIRAS, J. F. Evaluation of ruminal degradability profiles of forage using bags made from different textiles. **Revista Brasileira de Zootecnia**, v. 40, n. 11, p. 2565-2573, 2011.

WILLIAMS, C. H.; DAVID, D. J.; IISMAA, O. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. **Journal of Agricultural Science**, v. 59, n. 3, p. 381-385, 1962.

Received on June 13, 2013.
Accepted on July 8, 2013.