Revista Brasileira de Zootecnia

ISSN 1516-3598 (impresso)
ISSN 1806-9290 (*on-line*)
www.sbz.org.br

R. Bras. Zootec., v.38, n.6, p.1081-1087, 2009

Body composition and net and dietary macrominerals requirements of Nellore steers under grazing[1]

Vitor Visintin Silva de Almeida[2], Augusto César de Queiroz[3], Robério Rodrigues Silva[4], Fabiano Ferreira da Silva[5], Aline Cardoso Oliveira[2], Hermógenes Almeida de Santana Júnior[6]

[1] *Projeto financiado pelo Banco do Nordeste do Brasil/FUNDEC.*
[2] *Programa de Pós-graduação em Zootecnia - UFV.*
[3] *DZO/UFV, Viçosa, MG.*
[4] *DEBI/UESB, Itapetinga, BA.*
[5] *DTRA/UESB, Itapetinga, BA.*
[6] *Universidade Estadual do Sudoeste da Bahia - UESB.*

ABSTRACT - This experiment was carried out with the objective of determining the macrominerals (Ca, P, Mg, K and Na) requirements of Nellore steers under grazing. Twenty four Nellore steers (371 ± 14 kg of BW and 26 mo old) were used. Four steers were slaughtered at the beginning of the experiment (reference group), serving as a reference in subsequent study. The remaining 20 animals were weighed and distributed into a completely randomized design with four supplementation levels offer: 0.0 (mineral mixture - control), 0.3, 0.6 and 0.9% of BW, with five replications. The supplements, based on ground corn, soybean meal and/or urea, were previously balanced to achieve an average daily gain of 350, 650 and 850g, respectively, for the different supplementation levels offer. The contents of macrominerals retained in the animal body were determined by regression equations of the macrominerals body content logarithm in function of the empty body weight logarithm (EBW). Net macrominerals requirements for a gain of 1kg of EBW were obtained using the equation $Y' = b.10^a.X^{b-1}$, with a and b, respectively, the intercept and the regression coefficient of the prediction equations of macrominerals in the animal body contents for each macromineral considered. The concentrations of all macrominerals, in the empty body weight and gain of the empty body weight, decreased with the increase in the body weight. Total calcium and phosphorus dietary requirements are higher than those recommended in the literature.

Key Words: macrominerals, pasture, requirements, zebu cattle

Composição corporal e exigências líquidas e dietéticas de macrominerais de bovinos Nelore castrados em pastejo

RESUMO - Com o objetivo de determinar as exigências de macrominerais (Ca, P, Mg, K e Na) de bovinos Nelore castrados sob pastejo, foi conduzido um experimento com 24 novilhos da raça Nelore, castrados, com peso inicial de 371 ± 14 kg e 26 meses de idade. Quatro novilhos foram abatidos no início do experimento (grupo referência) para servir de referência nos estudos subsequentes. Os animais restantes (20) foram pesados e distribuídos em delineamento inteiramente casualizado com quatro níveis de suplementação: 0,0 (mistura mineral - controle); 0,3; 0,6 e 0,9% do peso corporal e cinco repetições. Os suplementos, à base de milho, farelo de soja e/ou uréia, foram balanceados previamente para promover ganhos médios diários de 350, 650 e 850 g, respectivamente. Os conteúdos de macrominerais retidos no corpo animal foram estimados por meio de equações de regressão do logaritmo do conteúdo corporal dos macrominerais, em função do logaritmo do peso de corpo vazio (PCVZ). As exigências líquidas dos macrominerais para ganho de 1 kg de PCVZ foram obtidas utilizando-se a equação $Y' = b.10^a. X^{b-1}$, em que a e b são o intercepto e o coeficiente de regressão, respectivamente, das equações de predição dos conteúdos corporais de cada macromineral considerado. As concentrações de todos os macrosminerais estudados, no corpo vazio e no ganho de corpo vazio, diminuíram com o aumento do peso vivo. As exigências dietéticas totais de cálcio e fósforo são superiores às recomendadas na literatura.

Palavras-chave: exigências, macrominerais, pasto, zebuínos

Received July 16, 2008 and accepted December 10, 2008.
Corresponding author: vsazootec@yahoo.com.br

Introduction

The nutritional deficiencies of cattle, especially in extensive systems, which are predominant in Brazil, are largely influenced by mineral deficiencies, because, in many situations, forages are deficient in one or more mineral elements.

Macrominerals are essential for the survival and growth of microorganisms in the rumen; because they contribute for the regulation of some physical and chemical properties of the ruminal environment, such as fermentation, osmotic pressure, buffering capacity and dilution rate (Ospina et al., 1999). Thus, they could improve the utilization of nutrients from the diet and, consequently, the performance of animals.

The nutritional macrominerals requirements for growth and fattening are usually estimated through the factorial method (ARC, 1980). This method is based on the net amount deposited in the animal body to meet growth and fattening, plus the amounts necessary to meet the inevitable loss of the animal body, which are the net maintenance requirements. The sum of maintenance and production fractions will be the total net requirement, which corrected by an absorption coefficient of inorganic element in the animal's digestive system, will result in the dietary requirement of this mineral (Silva, 1995).

The retention of minerals depends on the weight gain composition (bone, muscle and fat). Greater fat deposition reduces the deposition of minerals, and their requirements for animals, because the concentrations of inorganic elements in fat are less than in muscles and bones. Therefore, factors that modify the gain composition, such as the type of diet, sex, genetic group, age and body weight (BW) of animals, will affect the mineral composition and, consequently, the net weight gain requirements (Paulino et al., 1999).

Data on macrominerals requirements of Zebu cattle under grazing in Brazil are still not representative, and further researches in the area should be conducted. This study was conducted to evaluate the effect of different supplementation levels on body composition and net and dietary inorganic macroelements requirements of Nellore steers under grazing.

Material and Methods

The experiment was conducted between the months of August 2006 and February 2007. An area of 52.0 ha, composed of *Brachiaria brizantha* cultivar Marandu was split into eight paddocks of approximately 6.5 ha each, in a pizza design, with a drinking water source in the center.

Twenty-four Nellore steers with average initial weight of 371 + 14 kg and 26 months of age were used. Four steers were slaughtered at the beginning of the experiment (reference group), serving as a reference in subsequent study. The remaining 20 animals were weighed and distributed into a completely randomized design with four supplementation levels offer: 0.0 (mineral mixture – control), 0.3; 0.6 0.9 % of BW and five replications, supplements, based on ground corn and soybean meal and/or urea, were previously balanced to achieve an average daily gain (ADG) of 350, 650 and 850g, respectively, for the different supplementation levels offer (Table 1).

Supplements were daily offered at 10:00 am during the dry season, from August to November 17, 2006. From November 18, 2006, beginning of the rainy season until February 26, 2007, the steers were kept under the same feeding regime, only a mineral mixture offered *ad libitum* until they reached the established slaughter weight of 450 kg.

The evaluation of forage ingested by animals was performed by manual grazing simulation every 14 days. The collection of samples, based on Johnson (1978) procedure, was made and the type of material the animal was consuming was identified, aiming at collecting a sample similar to that ingested.

The fecal output was estimated using the chromic oxide (Burns et al., 1994) and was calculated based on the following equation: FO = COO/CCP, where FO is the daily fecal output (g/day), COO is the chromic oxide offered (g/day) and COF is the chromic oxide in feces (g/g DM). The chromic oxide was provided in a single daily dose (10 g/animal) wrapped in paper packs and introduced directly through an applicator in the esophagus of the animals for 12 consecutive days, seven days for adaptation and regulation of marker excretion flow and five days for feces collection.

Samples of forage, feces and supplements were incubated in the rumen of four fistulated animals for 144

Table 1 - Composition of ingredients of the supplements (% of DM)

Ingredient (%)	Supplementation level offer (% BW)			
	0 (control)	3	6	9
Corn meal	-	89.98	95.11	87.98
Soybean meal	-	-	-	10.40
Urea	-	5.00	2.44	0.06
Mineral mixture [1]	100	5.02	2.45	1.56

[1] Compostion: Ca, 18,5; P, 9; Mg, 0,4; S, 1 and Na, 11,7%; Se, 30, Cu, 1500; Zn, 4000; Mn, 1200; I, 150; and Co, 150 ppm.

hours, for the determination of the internal marker (IM) and indigestible ADF (iADF).

Estimates of individual voluntary intake was obtained using iADF (IM) in the following equation: DMI = $\{[(FO * IM_f) - IM_s] /) IM_{fo}\}$ + DMIS, in which DMI is dry matter intake (kg/day), FO is the fecal output (kg/day); IM_f is IM in feces (kg/kg),and IM_s is IM in supplements (kg/day) and IM_{fo} is IM in forage (kg/kg) and DMIS is DMI of supplements (kg/day).

Nutritional composition of forage and supplements were determined using procedures described by Silva & Queiroz (2002) (Table 2).

Animals were slaughtered at the pre-established slaughter weight of 450 kg of BW. After slaughter, the gastrointestinal tract was weighed, and this weight was added to the organs and other animal's body parts (carcass, head, leather, tail, feet and blood), for EBW determination. The relation between EBW and BW of the reference animals was used to estimate the initial EBW of animals that remained in the experiment. One animal from each supplementation level was randomly selected to represent the group, and samples were taken from head, feet (anterior and posterior) for subsequent physical separation of muscles, fat, bone and leather.

Blood samples were taken immediately after slaughter, conditioned in glass bottles and oven-dried at 55-60°C for 48 to 72 hours, for the dry matter (DM) content determination, and next, grounded in a ball mill and kept in suitable containers for subsequent macrominerals analysis, according to Silva & Queiroz (2002).

Table 2 - Nutritional composition of Brachiaria grass and supplements (% of DM)

Ingredient (%)	Brachiaria grass		Supplementation level offer (%BW)		
	Dry season	Rainy season	3	6	9
DM %	67.93	54.00	71.35	75.87	78.9
OM	93.90	93.70	93.93	94.74	95.33
CB	6.09	7.20	8.28	8.99	9.16
EE	2.20	2.20	2.39	2.67	2.93
TC	85.61	84.30	83.26	83.08	83.23
NFC	1.31	3.50	8.58	20.55	29.15
NDF	84.30	80.80	74.68	62.53	54.08
ADF	46.00	42.70	40.41	33.30	28.59
TDN	61.01	63.72	63.02	66.99	70.36
Ash	6.10	6.30	6.07	5.26	4.67
Ca	0.21	0.22	0.28	0.24	0.20
P	0.12	0.07	0.15	0.16	0.29
Mg	0.10	0.12	0.11	0.10	0.10
Na	0.02	0.03	0.16	0.20	0.16
K	0.86	0.62	0.58	0.52	0.54

DM = dry matter, CP = crude protein, EE = ether extract, TC = total carbohydrates, NFC = non-fibrous carbohydrates, NDF = neutral detergent fiber, ADF = acid detergent fiber, TDN = total digestible nutrients.

The carcass of each animal was divided into two halves, weighed, and then cooled in a cold chamber at -5 C, for 18 hours. After this time, samples from the left half-carcass were collected and weighed, corresponding to the 9th - 11th ribs section (HH section) for further dissection and prediction of the proportions of muscles, bones and fat in the carcass, according to equations recommended by Hankins & Howe (1946): muscle, Y = 16.08 + 0.80 X; adipose tissue, Y = 3.54 + 0.89 X and bone, Y = 5.52 +0.57 X, where X is percentage of components in the HH section.

Muscle and fat tissues were grounded, while the bone was sawed. A representative sample from each component was collected for the direct determination of minerals levels in the carcass.

Samples of rumen, reticulum, omasum, abomasum, small intestine, large intestine, internal fat, mesentery, liver, heart, kidneys, lungs, tongue, spleen, meat and industrial scraps (esophagus, trachea and reproductive system) were proportionally grouped composing a composite organs + viscera sample.

Except for blood samples, the composite organs + viscera + (200 g) muscle samples and fat from the carcass (200 g of each) were grounded, and leather (100 g), carcass bones, head and feet (200 g each), and tail (100 g), after sawed, were conditioned in glass bottles with capacity of 500 mL and put into a air forced oven at 105°C for a period from 48 to 96 hours, depending on the sample, for the determination of fat content in dry matter (FDM).

Subsequently, the samples were submitted to successive washing with petroleum ether, resulting in pre-defatted dry matter (PDDM).

The macrominerals contents in the animal body were determined according to their percentage concentrations in organs, viscera, leather, blood, tail, head (muscle, fat and bone), feet (tendon and bone) and separate constituents (fat, muscle and bone) of the HH section.

Regression equations of the logarithm of animal body Ca, P, Mg, Na or K content in function of the EBW logarithm were used to predict the net amounts of inorganic macrominerals retained in the body of animals from each supplementation level, and all together. The following equation was used: Y = a + bX + e, where Y is logarithm of the total content of inorganic macrominerals (kg) retained in the empty body, a is constant, b is regression coefficient of the logarithm of inorganic macrominerals content, according to the EBW logarithm; X is logarithm of EBW; e is random error.

Deriving the prediction equations for the inorganic macrominerals content in the animal body in function of the EBW logarithm, the prediction equations of the net Ca, P, Mg, K and Na requirements for gain of 1 kg of EBW were obtained as follows:

$Y' = b. 10^a. X^{b-1}$, where: Y' = net inorganic macrominerals requirement; and a and b = intercept and regression coefficient, respectively, of the prediction equations of inorganic macrominerals body content, and X = EBW (kg).

To estimate the maintenance requirements, and subsequently adding these values to the gain requirements in order to obtain the total dietary requirements, recommendations from the ARC (1980) and AFRC (1991) for total endogenous losses of Ca, P, Mg, Na and K were used, and bioavailability of these elements in feed, according to ARC (1980) and NRC (1996) (Table 3).

The results were statistically interpreted by analysis of variance and regression, using the SAEG (UFV, 2000). Comparisons between the regression equations for the evaluated parameters for each supplementation level were carried out to test the identity models, according to methodology recommended by Regazzi (1996).

Table 3 - Total endogenous losses and bioavailability of calcium, phosphorus, magnesium, sodium and potassium in feed

Element (kg)	Total endogenous loss[2]	Bioavailability (%)
Ca	[-0.74+0.0079BW+0.66DMI][3]	50[1]
P	1.6*[-0,06+0.693DMI]	68[1]
Mg	3.0 mg/kg BW/day	17[2]
Na	6.8 mg/kg BW/day	91[2]
K	Fecal – 2.6g/kg DMI[2]	
	Urinary – 37.5mg/kg BW	100[2]
	Saliva – 0.7g/100kg BW	
	Through skin – 1.1g	

[1]NRC (1996); [2]ARC (1980) e AFRC (1991); [3]Considering an intake of 2.0% BW- average intake observed in this work.

Results and Discussion

The estimate obtained for the EBW from the animal BW was: EBW= BW*0.8360. This value is close to 0.8575, observed by Zervoudakis et al. (2002), working with Holstein x Zebu crossbred steers, and 0.8506, observed by Fregadolli (2005), working with Nellore animals, both experiments conducted with animals in pasture.

To convert EBW gain (EBW gain) requirements into body weight gain (BW gain), 1 kg of EBW gain must be multiply by factor 0.9702.

No differences were observed, by the identity test of models, for the regression equations of the logarithm of macrominerals body content in function of the EBW logarithm for the four supplementation level. Thus, the regression equations considering all data together was used (Table 4).

The animal body Ca, P, Mg, Na and K contents per kg of EBW, and the net macrominerals requirements (Table 5) showed a decrease of macromineral contents with the increase in BW, which was expected.

Several authors have observed this trend (Silva, et al., 2002a; Paulino et al., 2004; Moraes, 2006). Possible explanations for this trend were based on the fact that, as the BW of the animal increased, the bone growth was practically null and the accumulation of fat tissue becomes more pronounced. The results obtained in this experiment could be justified by the fact that the bone tissue showed the higher minerals levels and fat did not present significant amounts of minerals (Silva, 1995).

Table 4 - Parameters of the logarithm regression equations of the macrominerals content (kg) in the empty body, according to the empty body weight (kg) logarithm of Nellore steers for the different supplementation levels (%), and all together

Supplementation level offer (%)	Parameter		r^2
	Intercept (a)	Coeficient (b)	
	Ca		
0.0 (control)	-1.0767	0.7289	0.50
0.3	-1.3467	0.8395	0.66
0.6	-1.1902	0.7765	0.75
0.9	-1.0552	0.7208	0.64
All together	-1.3360	0.8316	0.58
	P		
0.0 (control)	-1.0025	0.6393	0.57
0.3	-1.3983	0.7960	0.67
0.6	-1.7214	0.9251	0.50
0.9	-1.1273	0.6842	0.59
All together	-1.2281	0.7314	0.54
	Mg		
0.0 (control)	-2.8347	0.7102	0.51
0,3	-4.5144	1.3891	0.87
0,6	-3.8273	1.1139	0.84
0,9	-3.4751	0.9686	0.70
All together	-3.5539	1.0004	0.62
	Na		
0.0 (control)	-2.9924	1.0697	0.86
0.3	-2.9282	1.0451	0.96
0.6	-2.5770	0.9030	0.92
0.9	-2.8360	1.0081	0.97
All together	-2.7802	0.9850	0.86
	K		
0.0 (control)	-1.7989	0.5897	0.67
0.3	-1.7547	0.5722	0.63
0.6	-1.6922	0.5468	0.76
0.9	-1.8818	0,6255	0.66
All together	-1.7817	0.5825	0.63

Table 5 - Estimative of macrominerals content and net requirements per kg of gain empty body weight (EBW gain) of Nellore steers in function of body weight (BW)

BW (kg)	Ca	P	Mg	Na	K
		Content (g/kg EBW)			
300	18.26	13.43	0.28	1.53	1.65
350	17.79	12.89	0.28	1.52	1.55
400	17.39	12.43	0.28	1.52	1.46
450	17.05	12.05	0.28	1.52	1.39
		Net requirement (g/kg EBW gain)			
300	15.15	9.83	0.28	1.50	0.96
350	14.76	9.43	0.28	1.50	0.90
400	14.44	9.10	0.28	1.50	0.85
450	14.15	8.81	0.27	1.49	0.81

The animal body Ca content ranged from 18.26 to 17.05 g/kg EBW, while the net Ca requirements ranged from 15.15 to 14,15 g/kg EBW gain, as the BW increased from 300 to 450 kg. Net Ca requirements of 14.44 kg EBW gain, for an animal of 400 kg of BW, was higher than that observed (8.18, 11.19 and 11.95 g/kg EBW gain) by Véras et al. (2001), Silva et al. (2002a) and Paulino et al. (2006), respectively. It is important to stress that all results were obtained with Nellore animals under feedlot system. The values observed in this study were close to 13.02 g/kg of EBW gain, reported by Moraes (2006), working with Nellore animals in pasture.

The animal body P content ranged from 13.43 to 12.05 g/kg of EBW, while the net P requirements ranged from 9.83 to 8.81 g /kg of EBW gain, as the BW increased from 300 to 450 kg. The net P requirement of 9.10 g/kg of EBW gain for an animal of 400 kg was higher than values reported (4.96 and 8.31 g/kg EBW gain) by Paulino et al. (1999) and Silva (2002a), respectively, working with young bulls.

The net Ca and P requirements were higher than those observed by Fontes (1995), Véras (2001) and Silva (2002a), working with young bulls. These results, however, were not expected, because young bulls deposit less fat then steers and a normal tendency would be that Ca and P requirements reported by those authors would be higher than those observed in this work. However, this fact could possibly be justified, because the animals in this experiment did not have a high finishing fat degree, since they were on grass, which, consequently, did not reduce the body content of these minerals, increasing their net requirements.

Animal body Mg content was 0.28 g/kg EBW, while the net Mg requirements ranged from 0.28 to 0.27 g/kg of EBW gain, as the BW increased from 300 to 450 kg. Similar results were reported by Silva et al. (2002b), which showed net Mg requirements of 0.30 and 0.28 g/kg EBW gain, respectively, for Zebu animals of 300 and 450 of BW kg. Paulino et al. (2006), compiling data from different experiments conducted in Brazil with Zebu cattle, reported a net Mg requirement of 0.34g/ kg of EBW gain, for animals with 300 and 450 kg BW, respectively. In addition, the net Mg requirements were significantly lower than the constant value of 0.45 g/ kg of EBW gain, recommended by the ARC (1980).

Animal body Na and K contents were 1.53 to 1.52 and 1.65 to 1.39 g/kg EBW, respectively, while the net Na and K requirements were 1.50 to 1.49 and 0.96 and 0.81 g/kg EBW gain, respectively, as the BW increased from 300 to 450 kg. The net Na requirement (1.50 and 1.42 g/kg of EBW gain) was near that recommended by the ARC (1980) and Moraes (2006), respectively, with the latter working with Nellore animals in pasture. The net K requirements were lower than those recommended by ARC (1980) and obtained by Paulino et al. (2006) in Brazilian conditions.

Using the true absorption rates recommended by the NRC (1996) for Ca and P, of 50 and 68% respectively, and the ARC (1980) for Mg, Na and K, of 17, 91 and 100%, respectively (Table 3), net requirements for EBW gain (Table 5) and applying the factor 0.9702 to correct the net requirement for EBW gain in BW gain requirement, the dietary Ca, P, Mg, Na and K requirements per kg BW gain were estimated (Table 6)

Dietary Ca requirements for 1 kg of BW gain per day for an animal with 300 or 450 kg BW obtained in this work (29.40 to 27.46 g, respectively) were close to those reported by Paulino et al. (2006) for Zebu cattle (25.48 and 23.28 g/day). However, P requirements were always higher than those recommended by the NRC (1996), for the different BW.

In contrast to that observed for dietary gain requirements (Table 6), the total dietary requirements (Table 7) increased as the BW of animals increased, due to the contribution of maintenance requirements, which were in function of the BW of animals.

Table 6 - Dietary requirements for gain of macrominerals in g/kg body weight gain (BW gain) of Nellore steers in function of the body weight (BW)

BW (kg)	Dietary requirement for gain (g/kg BW gain)				
	Ca[1]	P[2]	Mg[3]	Na[4]	K[5]
300	29.40	14.02	1.60	1.60	0.93
350	28.65	13.45	1.60	1.60	0.88
400	28.01	12.98	1.60	1.60	0.83
450	27.46	12.57	1.60	1.59	0.79

EBW = BW*0.8360. [1]True absorption = 50%; [2]True absorption = 68%; [3]True absorption = 17%, [4]True absorption = 91%, [5]True absorption = 100%.

Tabela 7 - Total dietary macrominerals requirements (maintenance + gain of 1 kg BW) in g/day and in % of DM for an intake of 2.0% of BW of Nellore steers, in function of the body weight (BW)

BW (kg)	Ca		P		Mg		Na		K	
	g/day	%DM	g/day	%DM	g/day	%DM	g/day	%DM	g/day	%DM
300	40.25	0.67	26.51	0.44	5.14	0.09	3.77	0.06	20.26	0.34
350	41.54	0.59	27.99	0.40	5.99	0.09	4.14	0.06	23.26	0.33
400	42.95	0.54	29.49	0.37	6.85	0.09	4.50	0.06	26.25	0.33
450	44.45	0.49	31.00	0.34	7.70	0.09	4.85	0.05	29.25	0.33

EBW = BW*0.8360.

The total dietary Ca and P requirements (49.95 and 29.49 g/day, respectively), were higher than those recommendations (31 and 18 g/day, respectively) by the NRC (2000) and close and higher than those recommended (28.0 and 25.0 g/day, respectively) by the AFRC (1991), for a steer of 400 kg BW.

However, the total dietary Ca requirements were close to those estimated by Paulino et al. (2006) for zebu cattle in the Brazilian conditions (36.22 g /day). The NRC (2000) recommends that diets for beef cattle should contain 0.10, 0.06-0.08 and 0.60%, respectively, of Mg, Na and K in order to meet the requirements of animals. The total dietary Mg, Na and K requirements (Table 7) were 0.09, 0.06 and 0.33%, respectively, close, minimum and below those recommended by the NRC (2000).

Paulino et al. (2004), also using Zebu steers, reported daily total dietary Ca, P, Mg, Na and K requirements, considering an animal of 400 kg BW for 1 kg of ADG, of 33.32; 16.84, 8.38, 3.58 and 43.38 g respectively. Only total dietary P and K requirements differed most markedly, when compared with data obtained in this work, while the values of other requirements of minerals were close.

Conclusions

The net requirements for weight gain, calcium, phosphorus, potassium, sodium and magnesium decreases with the increase in body weight of the animals.

The total dietary Ca and P requirements were higher than those recommended by the NRC (2000), while K was lower and Na and Mg were similar.

Literature Cited

AGRICULTURAL AND FOOD RESEARCH COUNCIL - AFRC. Technical committee on responses to nutrients, Report 6. **A reappraisal of the calcium and phosphorous requirements of sheep and cattle**. Nutrition Abstract Review, v.61, n.9, p.576-612, 1991.

AGRICULTURAL RESEARCH COUNCIL - ARC. **The nutrient requirements of ruminants livestock**. London: Commonwealth Agricultural Bureaux, 1980. 351p.

BURNS, J.C.; POND, K.R.; FISHER, D.S. Measurement of forage intake. In: FAHEY JR., G.C. (Ed.) **Forage quality, evaluation and utilization**. Madison: America Society of Agronomy, 1994. p.494-531.

FONTES, C.A.A. Composição corporal, exigências líquidas de nutrientes para ganho de peso e desempenho produtivo de animais zebuínos e mestiços europeu-zebu. Resultados experimentais. In: SIMPÓSIO INTERNACIONAL SOBRE EXIGÊNCIAS NUTRICIONAIS DE RUMINANTES, 1., 1995, Viçosa, MG. **Anais...** Viçosa, MG: Universidade Federal de Viçosa, 1995. p.419-455.

FREGADOLLI, F.L. **Composição corporal e exigências nutricionais de novilhos de três grupos genéticos em pastejo**. 2005. 85f. Tese (Doutorado em Zootecnia) - Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, 2005.

HANKINS, O.G.; HOWE, P.E. **Estimation of the composition of beef carcasses and cuts**. [T.B.]: United Sates Department of Agriculture, 1946. p.1-19 (Technical Bulletin, 926).

JOHNSON, A.D., Sample preparation and chemical analysis of vegetation. In: MANETJE, L.T. (Ed.) **Measurement of grassland vegetation and animal production**. Aberustwyth: Commonwealth Agricultural Bureaux, 1978. p.96-102.

MORAES, E.H.B.K. **Desempenho e exigências de energia, proteína e minerais de bovinos de corte em pastejo, submetidos a diferentes estratégias de suplementação.** 2006. 151f. Tese (Doutorado em Zootecnia) - Universidade Federal de Viçosa, Viçosa, MG, 2006.

NATIONAL RESEARCH COUNCIL - NRC. **Nutrient requirements of beef cattle**. 7.rev.ed. Washington, D.C.: National Academy Press, 2000. 242p.

NATIONAL RESEARCH COUNCIL - NRC. **Nutrients requirements of beef cattle**. 7.ed. Washington, D.C.: National Academy Press, 1996. 242p.

OSPINA, H.; PRATES, E.R.; BARCELLOS, J.O.J. A suplementação mineral e o desafio de otimizar o ambiente ruminal para digestão da fibra. In: ENCONTRO ANUAL SOBRE NUTRIÇÃO DE RUMINANTES DA UFRGS – SUPLEMENTAÇÃO MINERAL DE BOVINOS DE CORTE, 1., 1999, São Gabriel. **Anais...** São Gabriel: Gráfica da UFRGS, 1999. p.37-60.

PAULINO, M.F.; FONTES, C.A.A.; JORGE, A.M. et al. Composição corporal e exigências de macroelementos minerais (Ca, P, Mg, Na e K) de bovinos não-castrados de quatro raças zebuínas. **Revista Brasileira de Zootecnia**, v.28, n.3, p.634-641, 1999.

PAULINO, P.V.R.; COSTA, M.A.; VALADARES FILHO, S.C. et al. Exigências nutricionais de zebuínos: minerais. **Revista Brasileira de Zootecnia**, v.33, n.3, p.770-780, 2004.

PAULINO, P.V.R.; VALADARES FILHO, S.C.; DETMANN, E. et al. Exigências nutricionais de zebuínos no Brasil: III. Minerais. In: VALADARES FILHO, S.C.; PAULINO, P.V.R; MAGALHÃES, K.A. (Eds.) **Exigências nutricionais de zebuínos e tabelas de composição de alimentos BR-Corte**. 1.ed. Viçosa, MG: UFV, DZO, 2006. 142p.

REGAZZI, J.A. Teste para verificar a identidade de modelos de regressão. **Pesquisa Agropecuária Brasileira**, v.31, n.1, p.1-17, 1996.

SILVA, D.J.; QUEIROZ, A.C. **Análise de alimentos** (métodos químicos e biológicos). Viçosa, MG: Universidade Federal de Viçosa, 2002. 235p.

SILVA, F.F.; VALADARES FILHO, S.C.; ÍTAVO, L.C.V. et al. Composição corporal e requisitos líquidos e dietéticos de macroelementos minerais de bovinos nelore não castrados. **Revista Brasileira de Zootecnia**, v.31, n.2, p.757-764, 2002a.

SILVA, F.F.; VALADARES FILHO, S.C.; ÍTAVO, L.C.V. et al. Exigências líquidas e dietéticas de energia, proteína e macroelementos minerais de bovinos de corte no Brasil. **Revista Brasileira de Zootecnia,** v.31, n.2, p.776-792, 2002b.

SILVA, J.F.C. Exigências de macroelementos inorgânicos para bovinos: o sistema ARC/AFRC e a experiência no Brasil. In: SIMPÓSIO INTERNACIONAL SOBRE EXIGÊNCIAS NUTRICIONAIS DE RUMINANTES, 1995, Viçosa, MG. **Anais...** Viçosa, MG: Universidade Federal de Viçosa, 1995. p.467-504.

UNIVERSIDADE FEDERAL DE VIÇOSA - UFV. **Sistema de Análises Estatísticas e Genéticas - SAEG**. Versão 8.0. Viçosa, MG: 2000. 142p.

VÉRAS, A.S.C.; VALADARES FILHO, S.C.; COELHO DA SILVA, J.F. et al. Composição corporal e requisitos líquidos e dietéticos de macroelementos minerais de bovinos nelore não-castrados. **Revista Brasileira de Zootecnia**, v.30, n.3, p.1106-1111, 2001.

ZERVOUDAKIS, J.T.; PAULINO, M.F.; DETMANN, E. et al. Conteúdo corporal e exigências líquidas de proteína e energia de novilhos suplementados no período das águas. **Revista Brasileira de Zootecnia**, v.31, n.1, p.530-537, 2002.