Scientific Notes

Macromineral requirements of Holstein calves

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Abstract – The objective of this work was to quantify the net requirements for the maintenance (NR_m) and growth (NR_g), as well as the retention coefficient (RC) of calcium, phosphorus, sodium, potassium and magnesium, of Holstein calves. The NR_m were 87.8, 20.8, 4.36, 2.21, and 1.01 mg kg^{-1} of empty body weight for Ca, P, Na, K, and Mg, respectively. The RC was 0.882, 0.473, 0.274, 0.088, and 0.052 for Ca, P, Na, K, and Mg respectively. The requirements of Ca and P of Holstein calves are higher than those estimated for adult animals.

Index terms: mineral nutrition, nutrient requirement, ruminants.

Exigências nutricionais de macrominerais para bezerros da raça Holandesa

Resumo – O objetivo deste trabalho foi quantificar as exigências nutricionais para a manutenção (NR_m) e o crescimento (NR_g), assim como o coeficiente de retenção (RC) de cálcio, fósforo, sódio, potássio e magnésio, de bezerros da raça Holandesa. As NR_m foram de 87,8, 20,8, 4,36, 2,21 e 1,01 mg kg^{-1} da massa de corpo vazio para Ca, P, Na, K e Mg, respectivamente. O RC foi de 0,882, 0,473, 0,274, 0,088 e 0,052 para Ca, P, Na, K e Mg, respectivamente. As exigências nutricionais de Ca e P de bezerros da raça Holandesa são maiores do que aquelas estimadas para animais adultos.

Termos para indexação: nutrição mineral, exigências nutricionais, ruminantes.

Mineral requirements for cattle are still estimated based on little information, and the results are often inaccurate (Suttle, 2010). For calves, accurate macromineral requirements have not been established yet, which leads to the use of a fixed concentration of minerals in starter and milk replacer (NRC, 2001), and specific data both for growth and maintenance are still needed. Recent studies with comparative slaughter aimed to estimate mineral requirements for different species and categories of ruminants (Pereira et al., 2016; Mendonça et al., 2017); however, advances as to these requirements for the nutrition of calves are scarce.

The objective of this work was to quantify the net requirements for the maintenance (NR_m) and growth (NR_g), and the retention coefficient (RC) of Ca, P, Na, K, and Mg of Holstein calves.

The management and slaughter procedures were approved by the ethics committee of the Universidade Federal de Viçosa (protocol no. 012/2012). More details on the study and results of intake, performance, digestibility, energy, and protein requirements are described by Rodrigues et al. (2016).

Forty-two noncastrated Holstein calves, averaging 35.6±5.9 kg of initial body weight at 3 days of age, were used. Out of all the experimental animals, ten were randomly selected as a baseline group and slaughtered at 3 days of age. The other 32 were arranged in a completely randomized design, in a 4×2 factorial arrangement. Three calves died in the course of the trial and were removed from the analysis. Four treatments were supplied in two meals (at 06:00 and 16:00 h), as follows: 2, 4, 6, and 8 kg per day of whole milk (239 g kg^{-1} crude protein; 257 g kg^{-1} fat; 8.1, 7.5, 3.3, 5.7, and 0.9 g kg^{-1} of Ca, P, Na, K, and Mg, respectively),. In all treatments, starter (193 g kg^{-1} crude protein; 133 g kg^{-1} of neutral detergent fiber; and 5.7, 4.6, 0.8, 3.8, and 3.4

g kg^{-1} of Ca, P, Na, K, and Mg, respectively) was offered ad libitum. From the eight replicates, four calves were slaughtered at 59 days of age, and the other four were weaned at the 60^{th} day; milk was replaced by Coastcross hay (*Cynodon dactylon*; 125 g kg^{-1} crude protein; 728 g kg^{-1} neutral detergent fiber; and 3.6, 2.5, 0.3, 4.0, and 2.0 g kg^{-1} of Ca, P, Na, K, and Mg, respectively), and the same starter ad libitum. Subsequently, these four calves were slaughtered, at 87 days of life. Intake was measured daily for each calf. Weekly samples of all feeds were collected to determine the mineral intake.

The slaughter was carried out by stunning the animals and causing a brain concussion, then subsequently sectioning the jugular vein. After slaughter, the gastrointestinal tract was cleaned, and the empty body weight (EBW) was quantified. Proportional composite samples of carcass and noncarcass components (NCC) were prepared for each animal.

All samples were lyophilized, milled (1 mm mesh sieve), and analyzed for dry matter, crude protein, organic matter, ash, and ether extract. The mineral concentrations were estimated through inductively coupled plasma optical emission spectrometry (ICP-OES). The previous digestion procedure was carried out according to Palma et al. (2015).

From the ten animals in the baseline group, the mineral content in EBW was regressed as a function of EBW. This regression was used to estimate the initial content of minerals in each slaughtered animal of 59 and 87 days of age. The retained minerals (RM) were estimated as the difference between the initial mineral content and the mineral content at slaughter.

To estimate the RC, RM was regressed as a function of ingested minerals according to the linear model $RM = a + b \times IM$, in which: RM are the minerals retained in the body (mg per day); IM are the ingested minerals (mg per day); a is the intercept and can be interpreted as the NR_m of each mineral; and b is the slope, considered to be the true RC.

The mineral content in the bodies of all animals was regressed as a function of EBW, including the BS animals, according to the allometric model $MC = a \times EBW^b$, in which: MC is the mineral content (g); EBW is the empty body weight (kg); and a and b are regression parameters. The derivative of this model was interpreted as the amount of minerals retained in 1 kg of empty body weight gain (EBWG). The predicting equation for NR_g was estimated from the derivative of the linear model $RM = a + b \times IM$, according to the model $NR_g = a \times b \times EBW^{(b-1)}$, in which: NR_g is the net requirement for growth (g kg^{-1} EBWG); EBW is the empty body weight (kg); and a and b are the parameters of the model. The dietary requirements (g per day) of each mineral can be calculated by dividing the net requirement by its respective RC.

Descriptive statistics of the analyzed data are shown on Table 1. Regression parameters were estimated using the NLIN and Mixed procedures of SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) for nonlinear and linear models, respectively. For the nonlinear models, the Gauss method was used for convergence. Significance was considered at 5% probability.

The regressions of NR_m, RC, NR_g, and dietary requirements according to EBW are shown in Table 2. All regression parameters were significant ($p<0.05$). The NR_m values were 87.8, 20.8, 4.36, 2.21, and 1.01 mg kg^{-1} EBW for Ca, P, Na, K, and Mg, respectively. The RC values were 0.882, 0.473, 0.274, 0.088, and 0.052

Table 1. Mean, minimum, maximum, and standard error of the mean (SEM) of body characteristics and composition of the calves.

Characteristic and composition	Mean	Minimum	Maximum	SEM
DMI (kg per day)	0.82	0.14	2.70	0.046
BW (kg)	59.8	21.0	112.0	4.09
EBW (kg)	54.2	20.5	93.5	3.37
EBW/BW	0.92	0.80	0.99	0.010
BWG (g per day)	491	143	890	41.3
EBWG (g per day)	400	125	705	36.4
EBWG/BWG	0.81	0.56	0.97	0.022
Carcass (g kg^{-1}) BW	515	416	590	5.9
Body composition (g kg^{-1}) EBW				
Crude protein	149	125	174	2.2
Ether extract	44.2	20.0	79.8	2.21
Ash	38.8	28.6	52.3	0.91
Ca	8.33	4.94	15.99	0.357
P	4.43	3.17	7.93	0.160
Na	1.25	0.67	1.72	0.034
K	0.675	0.455	0.963	0.0193
Mg	0.302	0.197	0.513	0.0099

DMI, dry matter intake; BW, body weight; EBW, empty body weight; BWG, body weight gain; EBWG, empty body weight gain.

for Ca, P, Na, K, and Mg, respectively. The negative exponent in the equations indicates a decrease of NR_g, whereas EBW increases for all minerals.

Hansard et al. (1954) observed 68 mg kg^{-1} BW for NR_m of Ca in 30-day-old calves fed only milk. In the present study, the greater estimates of NR_m are probably associated with the presence of a solid diet, since Ca excretion is related to intestinal mucosa losses (Suttle, 2010). Hansard et al. (1954) also observed a high-calcium RC of 0.97 with the reduction of animal growth and the increase of solid intake. The NR_m of P was higher than the recommendations of 12.0 by NRC (2001) and 16.1 mg kg^{-1} BW by Costa e Silva et al. (2015). Transforming the NR_m from the data of Costa e Silva et al. (2015) for a 150 kg BW steer on the basis of EBW, the requirements are 18.5 mg kg^{-1} EBW. Phosphorus can be recycled by the rumen as a salivary secretion, and this capacity is smaller in younger calves, which can increase the NR_m. The NRC (2001) considers a P absorption of 0.9 for calves fed only milk. Phosphorus RC value determined in the present work is smaller than the 0.82 found by Costa e Silva et al. (2015), and than the 0.58 by AFRC (1991), both based on animals heavier than 100 kg. Since we offered milk in the diets, this result was not expected, and more studies should evaluate the consistency of this lower-RC estimate for P in calves.

Estimates of the absorbed Ca and P requirements, for the growth of an animal weighing about 60 kg EBW, are 16.3 and 9.2 g kg^{-1} BWG, respectively, according to AFRC (1991) and NRC (2001). The NR_g of 10.5, 5.33, 1.24, 1.75, and 0.29 g kg^{-1} EBWG for Ca, P, Na, K, and Mg, respectively, were determined for Nellore cattle with a BW of 250 kg (Chizzotti et al., 2009). The growth composition of calves are probably more expressive in the visceral tissue due to the intense rumen and gut development, which could explain the lower-Ca NR_g. Hansard et al. (1954) observed higher exchangeable Ca in bones, and lower retention of Ca in nonskeletal components of calves with less than 6 months of age, which probably leads to lower retention.

The low RC observed for Na, K and Mg probably overestimated the dietary requirements of these minerals (Table 2). Since the gut is not fully developed, and the presence of milk in the diet can lead to different absorption metabolism, more specific studies on the physiological aspects and requirements of these minerals by animals lower than 100 kg BW are still needed.

Holstein calves requirements for Ca and P are higher than the values estimated for adult animals and consistent with the available literature on young animals.

Table 2. Parameters of equations to estimate retained minerals as a function of intake (mg per day), equations to estimate net requirements for growth, and dietary estimates of mineral requirements of Holstein calves.

Function	Mineral	Equation	RMSE	r^2	p-value	Dietary requirements EBW (kg)		
						40	60	80
		Retained (RM; mg BW^{-1}) as a function of ingested (IM; mg BW^{-1})				-------(g per day)-------		
Maintenance (a)	Ca	RM = -87.7 + 0.882 × IM	4.71	0.44	0.01	3.98	5.97	7.95
	P	RM = -20.8 + 0.473 × IM	3.26	0.44	<0.01	1.76	2.64	3.52
	Na	RM = -4.36 + 0.274 × IM	1.87	0.21	<0.01	0.64	0.95	1.27
	K	RM = -2.21 + 0.088 × IM	1.56	0.37	0.02	1.00	1.51	2.01
	Mg	RM = -1.01 + 0.052 × IM	0.91	0.49	<0.01	0.78	1.17	1.55
		Net requirements for growth (NRg) (g kg^{-1})				g kg^{-1} EBWG		
Growth (b)	Ca	$20.6 \times EBW^{-0.34}$	84.1	0.66	<0.01	6.66	5.81	5.26
	P	$9.50 \times EBW^{-0.38}$	41.9	0.74	<0.01	4.94	4.24	3.80
	Na	$2.22 \times EBW^{-0.21}$	9.47	0.89	<0.01	3.73	3.43	3.23
	K	$0.774 \times EBW^{-0.04}$	6.23	0.83	<0.01	7.59	7.47	7.38
	Mg	$0.518 \times EBW^{-0.19}$	2.79	0.78	<0.01	4.94	4.58	4.33

[(a)]Intercept is interpreted as net requirements for maintenance (NR_m), and slope as retention coefficient (RC). [(b)]Dispersion and significance statistics are from the generating predicted allometric equations. EBW, empty body weight; BW, body weight; EBWG, empty body weight gain.

DOI: 10.1590/S0100-204X2018000400015

Acknowledgments

To Fundação de Amparo à Pesquisa do Estado de Minas Gerais (Fapemig; APQ -01403-11) and to Instituto Nacional de Ciência e Tecnologia – Ciência Animal (INCT-CA), for financial support.

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Received on May 22, 2017 and accepted on August 2, 2017