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Energy and protein requirements of ¾ Zebu × ¼ Holstein crossbreds fed different calcium and phosphorus levels in the diet

[*Exigências de energia e proteína de bovinos cruzados ¾ Zebu × ¼ Holandês alimentados com diferentes níveis de cálcio e fósforo na dieta*]

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ABSTRACT

The aim of this study was to determine the nutritional requirements of energy and protein for maintenance and weight gain of crossbred cattle, as well as their efficiencies. Fifty ¾ Zebu × ¼ Holstein crossbred bulls with initial weights of 214±4kg and aged 11±0.2 months on average were used in this experiment. Four animals were used in the reference group; ten bulls were fed at the maintenance level; and the remaining 36 bulls were fed *ad libitum* and distributed in a completely randomized design in a 3×3 factorial arrangement, which had three feedlot periods (56, 112 or 168 days) and three calcium and phosphorus levels (low, medium and normal) in the diet. Four of the maintenance animals had their heat production measured by respirometry at the Laboratory of Metabolism and Calorimetry of UFMG. After slaughter, composite samples, referred to as carcass and noncarcass samples were obtained from each animal. The net energy requirements for maintenance (NE_m) and metabolizable energy for maintenance (ME_m) were 68.9 and 90.1 kcal/$EBW^{0.75}$/day, respectively. The efficiency (k_m) was 76.41%. The NE_m requirement determined in the respirometry chamber was 85.5 kcal/$kg^{0.75}$. The following equations were obtained for net energy for gain (NE_g) and net protein for gain (NP_g): NEg (Mcal/day) = $0.0505_{\pm 0.000986} \times EBW^{0.75} \times EBWG^{1.095}$ and NP_g (g/day) = $162.79_{\pm 18.2546} \times EBWG - 1.30_{\pm 5.3010} \times RE$. The efficiencies of fat and protein deposition were 70.04 and 15.12%, respectively. In conclusion, the requirements of NE_m for growing and finishing non-castrated ¾ Zebu × ¼ Holstein crossbred cattle are 68.9 kcal/$EBW^{0.75}$/day. Requirements of NE_g and NP_g can be obtained by the following equations: NE_g (Mcal/day) = $0.0505_{0.000986} \times EBW^{0.75} \times EBWG^{1.095}$ and NP_g (g/day) = $162.79_{\pm 18.2546} \times EBWG - 1.30_{\pm 5.3010} \times RE$.

Keywords: Crossbred bulls, minerals, nutritional requirements

RESUMO

Objetivou-se determinar as exigências nutricionais de energia e proteína para mantença e ganho de peso de bovinos cruzados, bem como suas eficiências. Foram utilizados 50 bovinos cruzados ¾ Zebu × ¼ Holandês, não castrados, com peso inicial de 214±4kg e idade média de 11±0,2 meses. Quatro animais foram usados para referência, dez para o grupo mantença e os 36 animais alimentados à vontade foram distribuídos em delineamento inteiramente ao acaso em esquema fatorial 3×3, sendo três períodos de confinamento (56, 112 ou 168 dias) e três níveis de cálcio e fósforo (baixo, médio e normal) na dieta. Quatro dos animais mantença foram encaminhados ao laboratório de metabolismo e calorimetria da UFMG para medição da produção de calor através da respirometria. Após os abates, foram obtidas duas amostras compostas para cada animal, denominadas carcaça e não carcaça. As exigências de energia líquida para mantença (ELm) e energia metabolizável para mantença (EMm) foram, respectivamente, de 68,9 e 90,1kcal/$PCVZ^{0,75}$/dia. A eficiência (km) foi de 76,41%. A exigência de ELm obtida na câmara respirométrica foi de 85,5kcal/$kg^{0,75}$. As equações obtidas para energia líquida de ganho (ELg) e

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proteína líquida de ganho (PLg) foram: EL_g (Mcal/dia) = $0,0505_{\pm 0,000986}$ × PCVZ ^{0,75} × GPCVZ ^{1,095} e PLg (g/dia) = $162,79_{\pm 18,2546}$ × GPCVZ – $1,30_{\pm 5,3010}$ × ER. As eficiências para deposição de gordura e de proteína foram de 70,04 e 15,12%, respectivamente. Conclui-se que as exigências de ELm para bovinos cruzados ¾ Zebu × ¼ Holandês não castrados em crescimento e terminação são de 68,9kcal/PCVZ^{0,75}/dia; e que as exigências de ELg e PLg podem ser obtidas pelas respectivas equações: EL_g (Mcal/dia) = $0,0505_{\pm 0,000986}$ × PCVZ ^{0,75} × GPCVZ ^{1,095} e PLg (g/dia) = $162,79_{\pm 18,2546}$ × GPCVZ – $1,30_{\pm 5,3010}$ × ER.

Palavras-chave: bovinos cruzados, minerais, requerimentos nutricionais

INTRODUCTION

In addition to the growth potential of animals (genetic breeding and management), an adequate nutritional plan and nutritional quality are required for all animal-rearing phases. Knowing the composition of feeds and their nutritional value makes it possible to meet the nutritional requirements of animals with greater efficacy. Thus, knowing the requirements of all animal categories is of extreme importance to adequately use feeds and consequently for the feeding costs.

Most of the best-known nutritional requirement systems in the world have been developed in temperate environments with breeds adapted to this type of climate (National, 2000; Agricultural, 1991; Commonwealth, 2007).

The first Brazilian Tables of Nutritional Requirements of Zebu Cattle (*Tabelas Brasileiras de Exigências Nutricionais de Zebuínos*; BR-CORTE) were published in 2006 by Valadares Filho and collaborators. These tables have become essential for optimizing animal performance and lowering the cost of diets formulated in Brazil. The second edition of these tables was published in 2010. However, additional information is required to improve the accuracy of estimates.

Animals originating from the crossing of the Zebu and Holstein breeds are not the basis of the data from which the BR-CORTE (2010) tables were developed. This type of animal is important for Brazil because the dairy cow–beef calf system is found on many farms.

Respirometry or indirect calorimetry can be used to determine the nutritional requirements of net energy for the maintenance of cattle without the need to slaughter them. It is only necessary to measure the O_2 intake and CO_2 production in animals after a long feed-deprivation period, which is a condition in which the production of methane and urinary loss of nitrogenous compounds are practically insignificant.

The aims of this study were to estimate the nutritional requirements of energy and protein, as well as their efficiencies, in crossbred cattle in a feedlot that were fed three levels of calcium and phosphorus in their diet and to estimate the fasting heat production of animals using respirometry.

MATERIAL AND METHODS

The study was approved by the Animal Welfare Commissioner of the Universidade Federal de Viçosa (number 46/2012).

This experiment was conducted in the experimental feedlot of the Department of Animal Science of the Universidade Federal de Viçosa, located in Viçosa, MG, Brazil.

Fifty ¾ Zebu × ¼ Holstein bulls with average initial weight of 214±4kg and aged 11±0.2 months were used in the experiment. Of the total, four were randomly chosen to compose the reference group, and ten were assigned to the maintenance group (seven were fed 12.0g DM/kg body weight and three were fed 13.0g DM/kg body weight). Four animals at the maintenance level (12.0g DM/kg BW) were fed normal levels of calcium and phosphorus and were tested in the respirometry chamber of the Laboratory of Calorimetry and Animal Metabolism of the Universidade Federal de Minas Gerais, where their heat production was estimated by O_2 intake and production of CO_2. Before entering the chamber these animals were subjected to a solid-feed deprivation period of 48 hours to reach their basal metabolism. Inside the chamber, the duration of measurement was approximately 24 consecutive hours (of which two were used for calibrating the chamber), during which CO_2 production and O_2 intake were measured. Heat production in the respirometry chamber was calculated using Brouwer's equation (1965).

The remaining animals were distributed in a completely randomized 3×3 factorial arrangement: three calcium and phosphorus levels (low, medium and normal) and three periods in the feedlot (56, 112 or 168 days), with four replications. The three levels of calcium and phosphorus were as follows: low = 1.8 and 2.2g/kg, respectively; medium = 3.0 and 2.4g/kg, respectively; and normal = 4.2 and 2.6g/kg, respectively, on a dietary dry-matter basis.

The diet was formulated according to BR-CORTE (2010); only the levels of calcium and phosphorus were modified to represent low, medium and normal levels of experimental diets. The lowest level of Ca and P did not contain a supplemental P source. The low level of calcium content was calculated to have 50% of the requirement indicated by BR-CORTE (2010), and the low level of phosphorus content was calculated to have 80% of the requirement. The medium levels were calculated to have 75% of the calcium requirement and 90% of the P requirement. The normal level should have 100% of the nutritional requirements of calcium and phosphorus, as indicated by BR-CORTE (2010).

All of the animals were initially weighed, identified and treated against ecto- and endoparasites and underwent a period of 30 days for adaptation to the experimental conditions.

The diet was composed of 60% corn silage on a dry-matter (DM) basis and 40% concentrate formulated from corn meal, soybean meal, urea/ammonium sulfate, limestone, dicalcium phosphate, common salt and a mineral mixture. The proportions of the ingredients in the concentrates and the diets and their chemical compositions are presented in Table 1.

Table 1. Proportions of feed components in the concentrates and in the diets and chemical compositions of the concentrates and diets, on a dry-matter basis

Components	Concentrates			Diets		
	Low[2]	Medium[2]	Normal[2]	Low[2]	Medium[2]	Normal[2]
	Proportion (g/kg DM)					
Corn silage	-	-	-	600.0	600.0	600.0
Corn meal	802.7	802.7	802.7	320.0	320.0	320.0
Soybean meal	147.7	147.7	147.7	59.0	59.0	59.0
Limestone	3.7	9.3	14.9	1.7	4.2	6.7
Dicalcium phosp.	0	3.3	6.9	0	1.5	3.0
Salt	4.6	4.6	4.6	2.0	2.0	2.0
Urea	20.4	20.4	20.4	9.0	9.0	9.0
Ammonium sulf.	2.3	2.3	2.3	1.0	1.0	1.0
Sand	18.4	9.2	0	8.0	4.0	0
Microminerals	0.5	0.5	0.5	0.2	0.2	0.2
	Chemical composition (g/kg DM)					
DM[1]	871.6	871.5	871.4	523.1	523.0	523.0
OM[1]	949.9	950.3	950.7	949.3	949.5	949.6
CP[1]	213.9	213.9	213.9	126.1	126.1	126.1
EE[1]	26.2	26.2	26.2	31.6	31.6	31.6
NDF_{ap}[1]	92.1	92.1	92.1	322.0	322.0	322.0
NFC[1]	653.9	654.3	654.7	485.6	485.8	485.9
Calcium	1.8	4.8	7.7	1.8	3.0	4.2
Phosphorus	2.4	2.8	3.2	2.2	2.4	2.6

[1]DM = dry matter; OM = organic matter; CP = crude protein; EE = ether extract; NDF_{ap} = neutral detergent fiber corrected for residual ash and protein; NFC = non-fibrous carbohydrates.
[2]Low = supplementation of 38 and 86% of the total described by BR-CORTE to meet calcium and phosphorus requirements, respectively; Medium = supplementation of 64 and 94% of the total described by BR-CORTE to meet calcium and phosphorus requirements, respectively; Normal = supplementation of 89% and 102% of the total described by BR-CORTE to meet calcium and phosphorus requirements, respectively.

After the adaptation period, the reference animals were slaughtered. The ratio of empty body weight (EBW) to shrunk body weight (SBW) obtained was used to estimate the initial EBW of the remaining animals.

Feed was supplied twice daily, and the supply was adjusted daily to keep the orts at approximately 5 to 10% of the total provided, with water permanently accessible to the animals. The amount of feed supplied was recorded daily, and samples of the corn silage and orts of each animal were also collected daily and frozen. The samples were collected and partially dried in a forced-ventilation oven at 55ºC for 72 hours and ground in a knife mill with a 1-mm screen sieve. A composite sample of orts and corn silage was elaborated for each sub-period of 28 days in proportion to the air-dried material of orts and corn silage every week. Composite samples were elaborated for each experimental period in proportion to the amount of each concentrate mixture.

The experiment was divided into three 56-day periods, with three slaughters at the end of each period.

For evaluation of the total digestibility of the diets, 18 animals were kept in a *tie stall* system in covered pens with concrete floors and provided with automatic drinkers and individual troughs. The other animals were kept in individual pens with concrete floors and provided with individual troughs and a concrete drinker, in an area covered with asbestos tile.

Digestibility testing was carried out immediately before each one of the three slaughter periods. Total fecal output was collected for three consecutive days. Twenty-four hours after collection, the feces were weighed and homogenized and a sample was taken. This sample was weighed and dried in a forced-ventilation oven at 55 ºC for 72 hours and ground in a knife mill (1mm). Subsequently, one composite sample was elaborated for each animal in each period, based on the air-dried weight on each collection day.

Samples of feeds, orts and feces were evaluated for their contents of dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent fiber (NDF) with corrections for residual protein and ash (NDFap), and ether extract (EE), as described in the AOAC (Association…, 2000). The mineral solution for the determination of mineral macro elements (calcium and phosphorus) was prepared via nitro-perchloric digestion. After dilution, the P contents were determined by colorimetry and the Ca contents were determined by atomic absorption spectroscopy.

The non-fibrous carbohydrate (NFC) contents were calculated as proposed by Detmann and Valadares Filho (2010). The total digestible nutrient (TDN) contents of the diets were estimated by summing the digestible nutrients.

The digestible energy (DE) intake by the animals was obtained from the digestible nutrients multiplied by their respective energy values, as described by the NRC (National…, 2001). The concentration of metabolizable energy (ME) was considered 82% of the DE (National…, 2000).

The intakes of DM and nutrients were calculated on the basis of the amounts ingested daily, obtained from the difference between the total feed supplied and the orts. An average was calculated for each 56-day period.

The metabolizable protein intake (MPI) was calculated as the sum of the true microbial protein and the digestible rumen-undegradable protein (RUP). The microbial crude protein intake (MCPI) was calculated as recommended by BR-CORTE (2010), considering 120g/kg TDN intake. We considered that MCP had 80% amino acids and that these amino acids had 80% digestibility (National…, 2001). The RUP intake was estimated from the CP intake minus MCP, divided by 0.80 (the intestinal digestibility of RUP).

At the end of each 56-day period, 12 animals (four for each level of calcium and phosphorus) were slaughtered. Half of the animals of the maintenance group were slaughtered at the end of 112 days, and the rest were slaughtered at the end of the 168 days. Before slaughter, the animals were subjected to a solid-food deprivation period of 16 hours. The animals were slaughtered by brain concussion and sectioning of the jugular vein for total bleeding. This was followed by washing of the gastrointestinal tract (rumen, reticulum, omasum, abomasum and small and large intestines). The heart, lungs, liver, spleen, kidneys, internal fat, diaphragm, mesentery, tail, trachea, esophagus, reproductive tract, gastrointestinal tract (after washing), head, hide, paws, blood and carcass were weighed for evaluation of empty body weight (EBW).

After slaughter, the carcass of each animal was divided into two halves, which were then cooled in a cold chamber at 4ºC for approximately 24 hours. After being cooled, all right half-carcasses were dissected into bones and muscle plus fat. These components were ground and a composite sample, referred to as a carcass sample, proportional to their presence in the empty body weight was formed.

The rumen, reticulum, omasum, abomasum, small and large intestines, internal fat, mesentery, liver, heart, kidneys, lungs, tongue, spleen, esophagus, trachea, and reproductive tract were ground in an industrial grinder, forming a composite and homogeneous sample of organs and viscera. Blood was collected after total bleeding and packaged in a plastic container. Head and hoof were also ground in an industrial grinder, and the hide was minced. These components were sampled, and a composite sample, referred to as the noncarcass component, proportional to the empty body weight, was later formed.

The two samples (carcass and noncarcass) obtained from each animal were lyophilized for 72 hours for quantification of the fat dry matter. Subsequently, they were partially degreased through successive washings with petroleum ether. The samples were ground in a knife mill for quantification of the levels of dry matter (DM), mineral matter (MM), crude protein (CP) and ether extract (EE), as described in the AOAC (Association…, 2000).

For conversion of shrunk body weight (SBW) into empty body weight (EBW), the ratios between EBW and SBW of the animals kept in the experiment were calculated. For conversions of average daily gain (ADG) into empty body weight gain (EBWG), the ratios between EBWG and ADG were calculated.

The fat removed in the partial degreasing process was added to the EE content for quantification of the total fat content in the animal body. The total CP, mineral matter, water and fat contents in the body of the animal were estimated by their percentages in the carcass and noncarcass samples.

The heat production of the four animals tested in the respirometry chamber was measured using Brouwer's equation (1965): $HP = 16.18VO_2 + 5.02VCO_2 - 2.17VCH_4 - 5.99UrN$, where HP = heat production (KJ); VO_2 = the volume of oxygen (L); VCO_2 = the volume of carbonic gas (L); VCH_4 = the volume of methane produced (L); and UrN = urinary nitrogen (g). We must emphasize that after 48 hours of fasting, the methane production and urinary losses of nitrogenous compounds (UrN) were considered insignificant.

The body energy content was obtained from the body contents of protein and fat and their respective caloric equivalents, using the equation proposed by the ARC (Agricultural…, 1980): $EC = 5.6405 \times CP + 9.3929 \times EE$, where EC = the body energy content (Mcal); CP = crude protein in the empty body (kg); and EE = ether extract in the empty body (kg).

Regression equations for retained energy (RE) versus EBWG were fitted for a given metabolic EBW ($EBW^{0.75}$), using the following model: $RE = a \times EBW^{0.75} \times EBWG^b$, where RE = retained energy (Mcal/$EBW^{0.75}$/day); $EBW^{0.75}$ = metabolic empty body weight (kg); EBWG = empty body weight gain (kg/day); and a and b are regression parameters.

Net energy requirements for maintenance (NE_m) were obtained from the intercept of the exponential regression between heat production (HP) and MEI. The model used was $HP = \beta_0 \times e^{\beta 1 \times MEI}$, where HP = heat production (Mcal/$EBW^{0.75}$/day); MEI = metabolizable energy intake (Mcal/$EBW^{0.75}$/day); β_0 and β_1 are regression parameters; and e is Euler's number.

The metabolizable energy for maintenance (ME_m, in Mcal/$EBW^{0.75}$/day) was determined by iteration, when MEI equaled HP.

The efficiency utilization of metabolizable energy for maintenance (K_m) was obtained from the ratio between the net and metabolizable energies for maintenance. To obtain the partial utilization efficiencies of metabolizable energy for fat and protein synthesis, we used the equation MEI = $\beta_0 + \beta_1 \times RE_p + \beta_2 \times RE_f$, where MEI = metabolizable energy intake (Mcal/$EBW^{0.75}$/day); RE_p = body energy retained in the form of protein (Mcal/$EBW^{0.75}$); RE_f = body energy retained in the form of fat (Mcal/$EBW^{0.75}$); β_0 = the metabolizable energy requirement for maintenance; and β_1 and β_2 = the efficiencies of deposition of energy as protein and fat, respectively.

To obtain the net requirements of protein for weight gain, we adjusted a model according to the energy retained by the test animals: RP = $\beta_0 \times$ EBWG + $\beta_1 \times$RE, where RP = retained protein (g/day); EBWG = empty body weight gain (kg/day); RE = retained energy (Mcal/day); and β_0 and β_1 are regression parameters.

The utilization efficiency of metabolizable protein for gain was calculated from a regression model for retained protein as a function of metabolizable protein intake, according to the model described in BR-CORTE (2010): RP = $\beta_0 + \beta_1 \times$ MPI, where RP = retained protein (g/$EBW^{0.75}$/day); MPI = metabolizable protein intake (g/$EBW^{0.75}$/day); and β_1 = utilization efficiency of metabolizable protein for gain (k).

The metabolizable protein requirement for maintenance was calculated according to the NRC (National…, 2000), where MPI was contrasted with the empty body weight gain of the test and maintenance animals: MPI= $\beta_0 + \beta_1 \times$ EBWG, where MPI = metabolizable protein intake (g/day) and EBWG = empty body weight gain (kg/day). The division of the intercept of the regression mentioned above by the average metabolic weight of the animals yields an estimate of the requirements of metabolizable protein for maintenance: $MP_m = \beta_0/EBW^{0.75}$, where MP_m = the metabolizable protein requirement for maintenance (g/$BW^{0.75}$/day); β_0 = the intercept of the regression presented above; and $EBW^{0.75}$ = the average metabolic empty body weight (kg).

The metabolizable protein requirement for gain (MP_g) was calculated by dividing the net protein requirement for gain by the utilization efficiency of metabolizable protein for gain.

All statistical procedures were carried out using SAS, the linear and nonlinear models obtained in this study were developed using PROC REG and PROC NLIN, respectively. For all tests, 0.05 was adopted as the critical probability level to verify the significance of the parameters of the models.

RESULTS AND DISCUSSION

After laboratorial analysis the treatments presented levels of calcium and phosphorus equal to the following proportions of the nutritional requirements recommended by BR-CORTE (2010): low = 38 and 86% for Ca and P, respectively; medium = 64 and 94%; and normal = 89 and 102%. Based on the recommendations of the NRC (National…, 2000), the mineral levels in the treatments amounted to low = 34 and 85% of the recommended dose for Ca and P, respectively; medium = 57 and 93%; and normal = 80 and 101%. Based on the AFRC system (Agricultural…, 1991), the mineral levels in the treatments were low = 43 and 57% of the requirements for Ca and P, respectively; medium = 71 and 62%; and normal = 100 and 67%.

The equation obtained for the ratio between empty body weight (EBW) and shrunk body weight (SBW) was EBW = $0.90339_{\pm 0.00236} \times$ SBW, where EBW = empty body weight (kg) and SBW = shrunk body weight. The ratio obtained was close to that used by BR-CORTE (2010), 0.895, and by the NRC (National…, 2000), 0.891. Silva (2011) obtained a ratio of 0.9143, working with growing and finishing Nellore bulls.

The equation obtained for the ratio between empty body weight gain (EBWG) and average daily gain (ADG) was EBWG = $0.93940_{\pm 0.00631} \times$ ADG, where EBWG = empty body weight gain (kg) and ADG = average daily gain (kg). The value obtained for this ratio is close to the 0.951 value recommended by the NRC (National…, 2000) and the 0.966 value recommended by BR-CORTE (2010), for crossbred cattle.

The heat production of the animals tested in the respirometry chamber was calculated using Brouwer's equation (1965) (Tab. 2). The heat production within the chamber (an average of 85.5 kcal/$EBW^{0.75}$) was higher than the heat production determined by the method of comparative slaughter (an average of 68.9 kcal/$EBW^{0.75}$). It should be noted that EBW is considered equivalent to the weight after a solid-feed deprivation period of 48 hours because an EBW/SBW ratio of 0.9034 of comparative slaughter animals cannot be considered to apply to the animals tested in the respirometry chamber because the feed deprivation of the comparative slaughter animals was only of solids and only lasted 16 hours. This observation may indicate that Brouwer's equation (1965) needs to be adjusted to estimate heat production for Zebu animals.

Heat production is not directly measured in comparative slaughter; it is calculated as the difference between metabolizable energy intake (MEI) and retained energy (RE) in the empty body weight. Relating heat production to MEI, we obtained the equation $HP = 0.0689_{\pm 0.00284} \times e^{4.5001 \pm 0.1610 \times MEI}$. The NE_m requirement was 68.9 kcal/$EBW^{0.75}$/day. This value is below that found in the literature: BR-CORTE (2010) indicates that this requirement is 74.2 kcal/$EBW^{0.75}$, whereas the NRC (National…, 2000) recommends a value of 77 kcal/$EBW^{0.75}$/day. The value we obtained in our study (69 kcal/$EBW^{0.75}$/day) is close to the basal metabolic rate suggested for homeothermic adult mammals, based on measurements performed in respirometry chambers (Poczopko, 1971).

Table 2. Means and standard deviations of heat production (HP) measured using the respirometry chamber.

Animal	Body Weight (kg)	VCO_2[1] (L/$kg^{0.75}$)	VO_2[1] (L/$kg^{0.75}$)	HP[1] (kJ/$kg^{0.75}$)	HP[1] (kcal/$kg^{0.75}$)
23	207	10.5	15.1	297.6	71.08
24	270	10.2	20.1	375.8	89.75
25	193	11.2	19.3	368.7	88.07
26	205	11.0	20.7	389.8	93.11
Average	-	10.7	18.8	357.98	85.5
Deviation	-	0.4	2.5	41.2	9.8

[1] VCO_2 = volume of carbonic gas produced; VO_2 = volume of oxygen consumed; HP = heat production.

Metabolizable energy for maintenance (ME_m) was calculated by iteration, where ME_m is the equality between MEI and HP; the value obtained was 90.17 kcal/$EBW^{0.75}$/day. This value is below the 112.4 kcal/$EBW^{0.75}$/day value suggested by BR-CORTE (2010) and is below the values suggested by others in the literature.

An equation for RE as a function of EBW and EBWG was obtained to estimate the energy requirements of gain for any weight and weight gain ranges: $NE_g = 0.0505_{\pm 0.000986} \times EBW^{0.75} \times EBWG^{1.095}$, where: NE_g = net energy requirement for gain (Mcal/day); $EBW^{0.75}$ = metabolic empty body weight (kg); and EBWG = empty body weight gain (kg). The equation obtained has an intercept close to that suggested by BR-CORTE (2010) for Zebu bulls (0.053).

The utilization efficiency of metabolizable energy for maintenance (K_m) was obtained by dividing NE_m by ME_m (68.9/90.17), resulting in a value of 0.7641. This value is greater than the value of 0.67 reported by Silva (2011) and by Chizzotti *et al*. (2008).

For conversion of the NE requirement into the ME requirement for gain, it is necessary to know the utilization efficiency of ME for weight gain (k_g). This efficiency can be obtained from the regression model for RE as a function of MEI (Fig. 1), where the slope coefficient, 0.21, is equal to the gain efficiency k_g. Silva *et al*. (2011) and Gionbelli (2010), using the same procedure mentioned above with Nellore cattle, obtained higher values: 0.33 and 0.38, respectively.

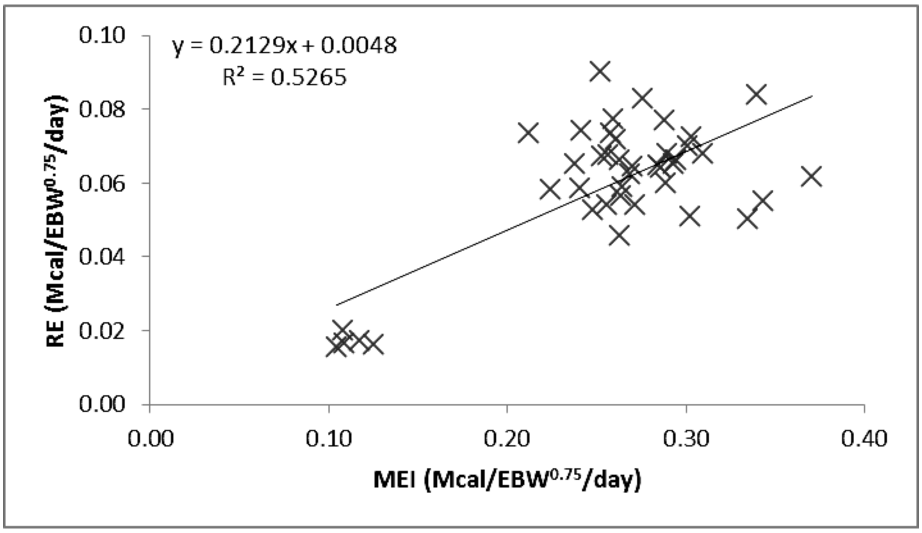

Figure 1. Retained energy (RE) as a function of metabolizable energy intake (MEI) of crossbred bulls.

Geay (1984) reported that the efficiencies of fat and protein deposition are different and that they are functions of the proportions of gain of each one of these components of the animal body. The equation obtained to generate the efficiency values was MEI = 0.09017 + 1.42 × RE_f + 6.61 × RE_p, where MEI = metabolizable energy intake (Mcal/EBW $^{0.75}$/day); RE_f = energy retained in the form of fat (Mcal/EBW$^{0.75}$/day); and RE_p = energy retained in the form of protein (Mcal/EBW$^{0.75}$/day). From the model proposed above, the variable efficiencies of fat and protein deposition were obtained as the inverses of the estimated coefficients: 1 ÷ 1.42 = 0.7042 = k_{fat} and 1 ÷ 6.61 = 0.1512 = k_{ptn}, where k_{fat} = fat deposition efficiency and k_{ptn} = protein deposition efficiency.

The deposition efficiencies of fat and protein obtained in this experiment were lower than those reported by Silva (2011), Gionbelli (2010) and Chizzotti *et al*. (2008), namely, 0.71 and 0.18, 0.83 and 0.25, and 0.79 and 0.34, respectively. These differences can be explained by the fact that the animals used in those experiments were slaughtered at different weights and also had lower fat deposition in their carcasses.

We obtained the following equation for metabolizable protein intake (MPI) versus EBWG: MPI = $152.38_{\pm 30.7376}$ + $351.12_{\pm 26.2730}$ × EBWG, where MPI = metabolizable protein intake (g/day) and EBWG = empty body weight gain (kg).

By dividing the intercept (152.38) by the average EBW$^{0.75}$(67.18) of the animals we obtain a requirement for metabolizable protein for maintenance (MP_m) equivalent to 2.26 g/BW$^{0.75}$. This value is well below the 3.8 g/BW$^{0.75}$ and 4.0 g/BW$^{0.75}$ values recommended by the NRC (National…, 2000) and BR-CORTE (2010), respectively.

From the fitted equation for retained protein (RP) as a function of MPI, we obtain the slope coefficient of 0.3711 or 37.11%, which is considered the utilization efficiency of metabolizable protein for gain. This value is lower than the 46.9% and 49.2% values recommended by BR-CORTE (2010) and the NRC (National…, 2000), respectively. The equation is RP = $-0.4437_{\pm 0.40128}$ + $0.3711_{\pm 0.04505}$ × MPI, where RP = retained protein (g/EBW$^{0.75}$/day) and MPI = metabolizable protein intake (g/EBW$^{0.75}$/day).

The protein retained in the animal body was estimated from the equation proposed:NP_g = $162.79_{\pm 18.2546}$ × EBWG – $1.30_{\pm 5.3010}$ × RE, where NP_g = net protein requirement for gain (g/day); EBWG = empty body weight gain (kg); and RE = retained energy (Mcal/day).

The parameter values obtained in this experiment were lower than those obtained by other authors (BR-CORTE, 2010; Gionbelli, 2010; Silva, 2011). This result may be because the animals used in our experiment had Holstein blood and deposited little body fat.

CONCLUSIONS

The net energy requirements for maintenance of ¾ Zebu × ¼ Holstein crossbred bulls are 68.9 kcal/$EBW^{0.75}$/day. The requirements for NE_g and NP_g can be obtained using the following equations: NE_g (Mcal/day) = 0.0505 × $EBW^{0.75}$ × $EBWG^{1.095}$ and NP_g (g/day) = 162.79 × EBWG – 1.30 × RE. The utilization efficiencies of metabolizable energy for maintenance and gain of growing and finishing ¾ Zebu × ¼ Holstein crossbred bulls are 76.41 and 21.29%, respectively. The efficiencies of deposition of energy in the form of fat and protein are 70.04 and 15.12%, respectively. The utilization efficiency of metabolizable protein for gain in ¾ Zebu × ¼ Holstein crossbred bulls is 37.11%.

REFERENCES

AGRICULTURAL And Food Research Council - AFRC. Technical Committee on responses to nutrients, A reappraisal of the calcium and phosphorus requirements of sheep and cattle (Report 6). *Nutrit. Abst. Rev.*. v.61, p.573-612, 1991.

AGRICULTURAL Research Council - ARC. *The Nutrient Requirements of Ruminant Livestock*. London: CAB International, 1980. 351p.

ASSOCIATION of Official Analytical Chemists - AOAC, Official Methods of Analysis, 17th ed. Association of Official Analytical Chemists, Gaithersburg. 2000.

BR-CORTE. *Exigências nutricionais de zebuínos puros e cruzados*. 2. ed. Suprema. Disponível em: http://cqbal.agropecuaria.ws/ webcqbal/brcorte/brcorte2010_eng.php. 2010.

BROUWER, E. Report of subcommittee on constants and factors in energy metabolism. In: Energy Metabolism (Ed. K.L. BLAXTER). *European association for animal production*. London: editora, 1965. p.441-443.

CHIZZOTTI, M.L.; TEDESCHI L.O.; VALADARES FILHO S.C. A meta-analisys of energy and protein requirements for maintenance and growth of Nellore cattle. *J. Anim. Sci., v.86,* p.1588-1597, 2008.

COELHO DA SILVA, J.F.; LEÃO, M.I. *Fundamentos de nutrição de ruminantes*. 1st ed. Piracicaba: editor, 1979. 380p.

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION – CSIRO. Nutrients requirements of domesticated ruminants. Collingwood, VIC: Commonwealth scientific and industrial research organization. 2007. 296p.

DETMANN, E.; VALADARES FILHO, S.C. On the estimation of non-fibrous carbohydrates in feeds and diets. *Arq. Bras. de Med. Vet. e Zootec*., v.62, p.980-984. 2010.

GEAY, Y. Energy and protein utilization in growing cattle. *J. Anim. Sci.*, v.58, p.766-778, 1984.

GIONBELLI, M.P. *Desempenho produtivo e exigências nutricionais de fêmeas nelore em crescimento.* 2010. 106f. Dissertação (Mestrado em Zootecnia) - Universidade Federal de Viçosa, Viçosa.

NATIONAL Research Council – NRC. *Nutrient requirements of dairy cattle*. 7th. ed. National Academy Press, Washington, D.C. 2001. 381p.

NATIONAL Research Council - NRC. *Nutrient requirements of beef cattle*. 7th. ed. National Academy Press, Washington, D.C. 2000. 242p.

POCZOPKO, P. Metabolic levels in adults homeoterms. Acta Theriologica, v.24, p.125-136, 1971.

SILVA, L.F.C. *Exigências nutricionais, validação de equações para a estimação da composição do corpo vazio e uso da creatinina para estimar a proporção de tecido muscular em bovinos nelore.* 2011. 126f. Dissertação (Mestrado em Zootecnia) - Universidade Federal de Viçosa, Viçosa.

VALADARES FILHO, S.C.; PAULINO, P.V.R.; MAGALHÃES, K.A. *Exigências nutricionais de zebuínos e tabelas de composição de alimentos* – BR CORTE. 1 ed. Viçosa: UFV, Suprema Gráfica Ltda, 2006. 142p.