Revista Brasileira de Zootecnia
© 2012 Sociedade Brasileira de Zootecnia
ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.41, n.3, p.762-770, 2012

Protein requirements for females of Nellore, Nellore × Angus and Nellore × Simmental fed on two forage:concentrate ratios[1]

Evaristo Jorge Oliveira de Souza[2], Sebastião de Campos Valadares Filho[3], Adriana Guim[2], Rilene Ferreira Diniz Valadares[3], Marcos Inácio Marcondes[3], Marcelo de Andrade Ferreira[2], Laura Franco Prados[3], Pedro del Bianco Benedeti[3]

[1] Financiado pela Fundação de Amparo à Pesquisa de Minas Gerais-FAPEMIG/Conselho Nacional de Pesquisa-CNPq.
[2] Universidade Federal Rural de Pernambuco.
[3] Universidade Federal de Viçosa.

ABSTRACT - This study aimed to determine the protein requirements for females of Nellore, F_1 Nellore × Angus and F_1 Nellore × Simmental fed on two concentrate levels (30 and 50%). Sixty heifers from three genetic groups with 18 months of age were used: 20 Nellore, 20 Nellore × Angus and 20 Nellore × Simmental. Twelve heifers of the reference group (four of each genetic group) were slaughtered at the beginning of the experiment. Another 12 heifers (four of each genetic group) were fed on the level of maintenance and 36 heifers (12 animals of each genetic group) were kept in power system *ad libitum* with 30% (six of each group) or 50% (six of each group) dietary dry matter in concentrate. Heifers were randomly assigned to six treatments in a 3 × 2 factorial arrangement (three genetic groups and two diets) with six replicates per treatment. Nine more heifers (three from each genetic group) were used to estimate the apparent digestibility coefficients of food in a parallel experiment. A model was fitted according to the protein retained as function of the gain of empty body weight (EBW) and retained energy (RE) to calculate the protein net requirements. To estimate the metabolizable protein requirements for maintenance the consumption of metabolizable protein was contrasted with EBW. The joint use of the equation net protein gain (NPG) = 197.40 × EBWg - 11.14 × RE is recommended to predict the protein net requirements for weight gain. Protein and metabolizable protein net requirements for maintenance are 1.07 and 3.88 g/$EBW^{0.75}$/day, respectively. The use efficiency of metabolizable protein for gain of all genetic groups is 37.04%.

Key Words: crossbred, heifers, metabolizable protein and net protein

Introduction

Requirements of international markets for meat quality compel producers to slaughter young animals, forcing them to accelerate their growth rate, resulting in quality products and higher productivity. The economic return not always increases with the growth rate improvement, since such expansion often results in increased costs. One of the ways to lower the age of slaughter is the use of cross breeding programs of *Bos taurus taurus/Bos taurus indicus*, enabling the combination of important productive features, in addition to obtaining the hybrid vigor.

The content of defatted dry matter of weight gain, body weight, sex, age and genetic group are the main factors influencing the net requirements of protein for growing and finishing cattle. According to Garrett (1980), breed has much more penetrating influence on the composition of body weight or carcass weight than the nutritional level. The NRC (2000) reports that larger breeds have higher protein requirements at maturity.

Due to the variation in gain composition, protein requirements differ between sex classes; non-castrated males have higher requirement than the castrated ones, and they are superior to females of the same age, since non-castrated males deposit more lean tissue in the body than castrated males and females. Paulino et al. (2009), working on Nellore of different sex classes (non-castrated males, castrated males and females) found differences in the rates of muscle increase. The authors reported that non-castrated males had higher muscle deposition in the carcass compared with females, with castrated males at an intermediate position.

Knowledge of body composition and nutritional requirements allows developing mathematical models that simulate growth of different genetic groups, thus helping in the development of nutritional strategies for cattle production in Brazil. In this context, there are few studies conducted in the country related to nutritional requirements of females for slaughter.

The objective of this study was to determine the protein requirements for females of Nellore, F_1 Nellore × Angus and F_1 Nellore × Simental.

Received October 6, 2010 and accepted August 23, 2011.
Corresponding author: evaristo@uast.ufrpe.br

Material and Methods

The study was conducted at the Department of Animal Science, Universidade Federal de Viçosa, Minas Gerais. The experiment lasted 142 days, 30 days for adaptation of animals to the experimental conditions and 112 days for data collection.

Sixty heifers of three genetic groups with 18 months of age were used: 20 Nellore with average 247.80±16.71 kg, 20 F_1 Nellore × Angus with average 292.94±17.85 kg and 20 F_1 Nellore × Simental with average 258.64±34.06 kg. Four heifers of each genetic group were slaughtered at the end of the adaptation period (reference group) to estimate initials body composition and empty body weight (EBW) distributed in the treatments. From the total number of heifers, 12 (four of each genetic group) were fed on the maintenance level (1.1% body weight in dry matter) with diet containing 30% concentrate and 36 heifers (12 animals of each genetic group) were kept in feeding system *ad libitum* with 30 (six in each group) or 50% (six from each group) dry matter (DM) of the diet in concentrate. Nine more heifers were used to estimate the apparent digestibility coefficients in the diet in a parallel experiment (three from each genetic group).

Experimental diets were composed of corn silage, corn meal, soybean meal, livestock urea, sodium bicarbonate, magnesium oxide, mineral mixture and sodium chloride (Tables 1 and 2).

Heifers were randomly assigned to six treatments (completely randomized design) in a 3 × 2 factorial arrangement, with three genetic groups and two diets (low and high proportion of concentrate *ad libitum*), with six replicates per treatment. Animals were housed in individual cages equipped with concrete feeder and drinker.

Animals were fed twice a day (8 and 16 h) and adjusted daily, allowing surplus of around 5% the supplied with water permanently available to the animals.

To determine the weight gain, heifers were weighed every 28 days. Daily samples of concentrates, corn silage and surplus from each animal were collected. Samples were grouped proportionally in each period of 28 days, making composite samples, which were previouly oven-dried (65 °C) and ground in a mill with 1-mm mesh sieve for subsequent laboratory analyses. After the experimental period, slaughters started with six animals slaughtered per day (one of each genetic group and concentrate level), with one-day interval for carcasses dissection between each slaughter.

Before slaughter, animals were fasted of solids for 16 hours. The slaughter was carried out via stunning and jugular section for total bleeding, the gastrointestinal tract (rumen, reticulum, omasum, abomasum and small and large intestines) of each animal was emptied, washed and weighed.

Weights of heart, lungs, liver, spleen, kidneys, internal fat, industrial meat, mesentery, tail and trimmings (esophagus, trachea and reproductive system), along with the washed gastrointestinal tract were added to the other body parts (carcass, head, leather, feet and blood) for determination of empty body weight (EBW).

The estimated initial EBW of animals that remained feeding was obtained by the ratio between EBW and body weight (BW) of reference animals.

Within each treatment (genetic group and diet), two animals were randomly selected and had head and limbs (anterior and posterior) sampled for subsequent physical separation of muscles, fat, bone and leather. The average composition of head and limbs of these animals was used to estimate the composition of animals which did not have their limbs or head sampled.

After slaughter, the carcass of each animal was divided into two half-carcasses, which were weighed and then cooled in a cold chamber at -5 °C for 18 hours. After this time, all right half-carcasses were separated into muscle, fat and bones; rumen, reticulum, omasum, abomasum, small intestine, large intestine, internal fat, mesentery, liver, heart, kidney, lung, tongue, spleen, industrial meat and trimmings were ground in industrial cutter for 20 minutes to remove a homogeneous sample of organs and viscera.

Table 1 - Chemical composition of feed ingredients

Nutrients	Feedstuffs		
	Corn silage	Corn meal	Soybean meal
Dry matter (DM),%	28.27	87.93	87.36
Organic matter, %DM	94.93	98.84	93.93
Crude protein, % DM	6.96	8.27	51.95
Ether extract, % DM	2.52	4.15	3.71
Neutral detergent fiber (NDF), % DM	50.82	10.83	15.18
NDF corrected for ash and protein, % DM	46.08	10.06	9.47
Non-fibrous carbohydrates, % DM	34.63	75.59	23.08

Table 2 - Proportion of ingredients and percent and nutritional composition of experimental diets

Ingredients (% in DM)	Concentrate levels	
	30%	50%
Corn silage	69.10	50.00
Corn meal	23.37	38.95
Soybean meal	5.49	9.16
Urea + ammonium sulfate	1.14	0.40
Sodium chloride	0.30	0.50
Mineral mixture[1]	0.30	0.50
Magnesium oxide	0.10	0.17
Sodium bicarbonate	0.20	0.33
Nutrients	Nutritional composition	
Dry matter (DM),%	38.11	45.35
Organic matter, % DM	94.99	94.96
Ether extract, % DM	2.92	3.21
Crude protein, % DM	12.46	12.42
Metabolizable energy, Mcal/kg DM [2]	2.35	2.67
Neutral detergent fiber (NDF), % DM	38.48	30.84
NDF corrected for ash and protein, % DM	34.85	27.89
Non-fibrous carbohydrates, % DM	46.50	52.04

[1] Mineral mixture: Ca - 24.0%; P - 17.4%; Co - 100.0 ppm; Cu - 1,250.0 ppm; Fe - 1,795.0 ppm; Mn - 2,000 ppm; Se - 15.0 ppm; Zn - 5,270 ppm; I - 90.0 ppm.
[2] Estimated from the total digestible nutrients intake.

Blood samples were collected immediately after slaughter, packed in glass container and oven-dried (65 °C, 72 hours). Subsequently, samples were ground in a ball mill and packed into containers for further analysis of dry matter, mineral matter, total nitrogen and ether extract as described by Silva & Queiroz (2002), with crude protein content as the product between total nitrogen and the factor 5.88, as suggested by Baldwin (1995). With the exception of blood, samples from more visceral organs, muscle plus fat of the right half-carcass, leather and bones samples were lyophilized. Subsequently, samples were subjected to successive washings with petroleum ether, resulting in the pre-defatted dry matter. Afterwards, samples were ground in a ball mill for subsequent determinations of dry matter, mineral matter, total nitrogen and ether extract as described by Silva & Queiroz (2002), with crude protein content as the product between total nitrogen and factor 5.88 as suggested by Baldwin (1995).

The determination of body energy was obtained from body levels of fat and protein and their caloric equivalents, according to the equation recommended by ARC (1980): $EC = 5.6405 \times + 9.3929\ Y$ where EC = energy content (Mcal); × = body protein (kg); Y = body fat (kg). The protein content in the body of animals of each treatment and all treatments together were estimated by nonlinear equations of the protein content of reference and animals on performance in function of EBW according to the following model: $BP = \beta 0 \times EBW^{\beta 1}$, where BP is the content of body protein (kg), EBW is empty body weight and β_0 and β_1 are regression parameters.

From the regression parameters presented above, net requirements of protein per pound of gain in empty body weight were estimated by the derivative of the equation above, according to the model: $NPg = \beta 0 \times b1 \times EBW^{\beta 1\text{-}1}$ 1,000 in which NPG is the net protein gain (g/EBW) and β0 and β1 are regression parameters. To calculate the net requirements of protein for gain and any range of performance, a model according to the energy retained with those animals in performance was adjusted: $NPG = \beta 0 \times EBW + \beta 1 \times RE$, where EBW is the gain of empty body weight (kg/day), RE is the retained energy (Mcal/day) and $\beta 0$ and $\beta 1$ are regression parameters.

For calculation of protein requirements for maintenance, the model suggested by Valadares Filho et al. (2010) was adopted first, in which the consumption of metabolizable protein was contrasted with the gain of empty body weight for animals on performance and maintenance: $_mPI = \beta 0 + \beta 1 \times EBW$ in which $_mPI$ is metabolizable protein intake (g/day) and EBW is the gain of empty body weight (kg/day) and $\beta 0$ and $\beta 1$ are regression parameters. The division between this regression intercept by the average metabolic weight of animals allowed estimating the metabolizable protein requirements for maintenance ($\beta 0/BP^{0.75}$, $g/BP^{0.75}/day$).

Alternatively and using the same group of animals, the protein retained was plotted as function of metabolizable protein intake according to the model: $PR = \beta 0 + \beta 1 \times {}_mPI$, where PR is the protein retained ($g/EBW^{0.75}/day$), $_mPI$ is the metabolizable protein intake ($g/EBW^{0.75}/day$) and $\beta 0$ and $\beta 1$ are regression parameters.

The module $\beta 0$ of this model represents the net requirements of protein for maintenance, and $\beta 1$, the use efficiency of metabolizable protein for gain.

Coefficients $\beta 0$ and $\beta 1$ of the last two models presented were estimated by the method of orthogonal regression of Fuller (1987), which considers both model variables have random errors associated with them. The equation parameters were obtained as follows: $\beta_0 = \overline{Y} - \beta_1 \overline{X}$; $\beta_1 = (\sigma^2_y - \sigma^2_x + ((\sigma^2_y - \sigma^2_x)^2 + 4\sigma_{xy}{}^2)^{\wedge 0.5}))/2\sigma_{xy}$, where x is the average metabolizable energy intake, Y is the average energy retained σ^2_x is the x variance, σ^2_y is the variance of Y and σ_{xy} is the covariance between x and Y.

The digestibility assay used to estimate digestibility of diets in the performance experiment was conducted in three Latin squares (3 × 3), one square for each genetic group consisting of three heifers, three experimental periods of 28 days each and three diets (low and high level of concentrate, *ad libitum*, and low level of concentrate at the level of maintenance). In the third week of each experimental period (Latin square), total feces were collected for three consecutive days to estimate the apparent digestibility of nutrients, total digestible nutrients (TDN) and metabolizable energy (ME). The conversion of digestible energy (DE) in ME was in accordance with the NRC (2000) according to the equation ME = 0.82 *DE (considering that a pound of TDN is equal to 4.409 Mcal DE).

Samples of corn silage, concentrate ingredients (corn, soybean meal, urea and minerals), remainders and feces were analyzed in the laboratory and their dry matter content (DM), mineral matter (MM) crude protein (CP), ether extract (EE) and neutral detergent fiber (NDF), by methods described by Silva & Queiroz (2002). The Ankom® System was used to assess NDF, with modification of the bag used (5.0 × 5.0 cm, 100-μm porosity), which was made using non-woven fabric - TNT (100 g/m^2).

Total carbohydrate contents (CHO) were estimated by the proposed equation of Hall et al. (1999): CHO = 100 - (% CP +% EE +% Ash). Due to the presence of urea in the diets, non-fibrous carbohydrates contents were estimated as follows: NFC% = 100 - [(% CP - %CP Urea + %Urea) + % NDF +% EE +% MM], according to Hall (2000).

For estimation of total digestible nutrients (TDN) the equation described by Weiss (1999) was used, in which = $DCP + DEE*2.25 + DNFC + DNDF_{ap}$, where DCP, DEE, DNFC and $\mathrm{DNDF_{ap}}$ mean, respectively, digestible crude protein, digestible ether extract, digestible non-fibrous carbohydrates and neutral detergent fiber (corrected for ash and protein). The sum of digestible true microbial protein and rumen undegradable digestible protein was used to calculate the metabolizable protein intake. Microbial protein was calculated considering efficiency of 130 grams microbial protein per pound of TDN consumed, 80% are amino acids with 80% digestibility (NRC, 2001). Protein consumption not degraded in the rumen was obtained by the difference between crude protein and microbial protein production, and assuming 80% digestibility for microbial protein.

Results were analyzed statistically by analysis of variance and regression using the statistical package SAS (Statistical Analysis Systems, version 9.2). Comparisons between regression equations of parameters evaluated for each treatment were performed according to the methodology recommended by Regazzi (1996) to test identity of the models.

Results and Discussion

An overall equation for predicting the empty body weight (EBW) was obtained once the concentrate level, genetic group and the concentrate level × genetic group interaction had no significant effect on this parameter (P>0.05). The EBW was estimated as follows: EBW (kg) = 0.91 (±0.018) × BWF (kg), where BWF is body weight at fast. The value of 0.91 found in this study is consistent with those from 0.85 to 0.95 found in the literature (NRC, 2000; Backes et al., 2002; Paulino et al., 2004; Valadares Filho et al., 2006; Chizzotti et al., 2008).

The ratio between average daily gain (ADG) and gain in EBW was 0.90 (EBW, kg/day = 0.90 (±0.050) × ADG, kg/day), given that the level of concentrate, genetic group and the concentrate level × genetic group interaction had no significant effect (P>0.05). Therefore, 1 kg BWF average daily gain is equivalent to 0.90 kg EBW. The ADG:EBW ratio found in this study was lower than the 0.92 found by Marcondes et al. (2010) working on the same genetic groups (Nellore, Nellore × Angus and Nellore × Simmental). The highest ratio found by the authors is consistent, since they worked with males.

Equations describing contents of body protein were estimated: Nellore> Body protein (kg) = 0.2132 × EBW$^{0.9491}$; Nellore × Angus> Body protein (kg) = 0.2087 × EBW$^{0.9555}$; Simmental × Nellore> body protein (kg) = 0.2493 × EBW$^{0.9285}$; this can be better viewed in the ratio between body protein content as a function of increasing body weight for the three genetic groups (Figure 1).

Models identity test applied to the equations indicated no significant difference (P>0.05) between genetic groups; therefore a joint equation was generated, which is common to all groups: body protein (kg) = 0. 2188 × EBW$^{0.9477}$.

The model presented above is a representative of the biological behavior of the animals, since the total protein content increases with body weight (ARC, 1980; Owens et al., 1993). On the other hand, in terms of concentration, i.e., g/kg EBW, body content of protein decreases with

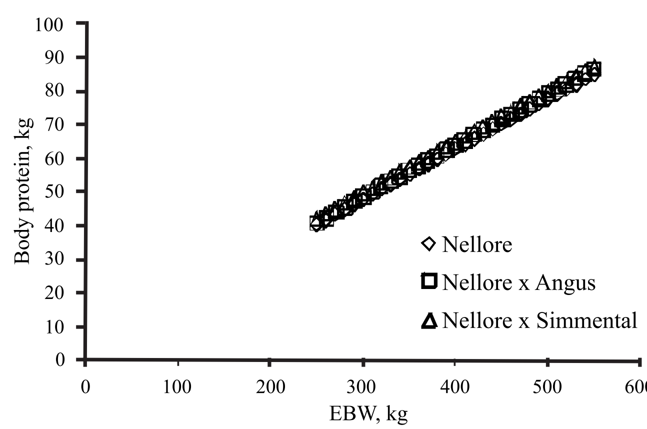

Figure 1 - Protein content in the empty body for different weights of empty body (EBW) for the three genetic groups evaluated.

advancing age, which shows reduction in net protein requirements for gain with increasing body weight.

Deriving this equation for predicting the body content of protein for EBW, net protein requirements for EBW gain were estimated. Data confirm what was mentioned about reduction in protein requirements as body weight increases (Table 3). It is noteworthy that no significant difference (P>0.05) in net protein requirements for gain between genetic groups was observed.

It can be observed that net requirements of protein for gain decrease in a marked way with increasing weight. This behavior can be explained by the growth curve in cattle. According to Berg & Butterfield (1976) and Owens et al. (1993), the gain in protein per pound of tissue gained decreases as body weight rises parallel to increases in fat concentrations, indicating the slowing of muscle growth and faster development of adipose tissue, concomitantly with increased body weight.

Freitas et al. (2006), working on Nellore, Nellore × Angus, Nellore × Simmental and Nellore × Brown Swiss considering the weight range from 250 to 550 kg, observed 10.6% reduction in protein requirements for weight gain (g/kgEBWg/day). Gourlat et al. (2008) found protein requirements for weight gain of 153, 140, 164 and 142 g/kgEBWg/day for Nellore, Nellore × Angus, Nellore × Simmental and Nellore × Canchim, respectively.

From the data on weight gain in empty body (kg/day) and retained energy (RE, Mcal/day) of animals, equations were built to estimate the retained protein that directly reflects in net requirements of protein for any growth range. Thus, equations were built for each genetic group: Nellore> NPG = 257.56 × EBW - 39.26 × RE; Nellore × Angus> NPG = 177.32 × EBW - 8.99 × RE; Nellore × Simmental> NPG = 259.10 × EBW - 11.04 RE, where NPG is net protein for gain (g/day), EBW is the gain in empty body weight (kg/day) and RE is the retained energy (Mcal/day). For construction of equations describing the estimation of retained protein described above, the method of nonlinear models was adopted, using the Gauss-Newton iterative algorithm. There was no significant difference (P>0.05) on any of the factors described above; therefore, acombined equation was generated for all genetic groups: NPG = 197.40 × - EBW 11.14 × RE.

The combined equation generated to estimate the net requirements of protein for gains reflects the growth curve of the animal, once the RE coefficient is negative, indicating that the highest RE value results in decreased protein retained. According to Paulino et al. (2004), the highest values of energy retention are associated with higher fat contents in EBW and consequently lower protein amount.

For the NRC (2000), protein requirements for growing animals are based on the expected composition of EBW gain and directly influenced by factors such as gender and breed. For the same body weight, animals that reach maturity with higher weights have higher protein requirements. However, this behavior was not observed in this research, which is the reason why a common equation was generated for all genetic groups. Similar behavior was found by Silva et al. (2002a), who, working on a combined analysis of data from 14 experiments conducted in Brazil with Zebu animals, F1 European × Zebu (European breeds and Zebu matrix) crossbred dairy (1/2, 3/4 and 5/8 Holstein-Zebu) and Holstein, recommended to join Zebu and F1 European × Zebu requirements and crossbred dairy and Holstein requirements. Thus, values found by these authors hypothesize that differences in nutritional requirements of proteins differ only between zebu and dairy crossbred. Using the RE estimation (4.15 Mcal/day) for a heifer weighing 350 kg body weight and 1 kg/day average daily gain, according to the RE equation as function of EBW and EBW gain ($RE = 0.0611 \times EBW^{0.75} \times EBWg^{0.6718}$) proposed by Souza et al. (2012) with data from this experiment, 140.23 g/day retained protein (RP) could be found. Substituting these same values in the equations proposed by Moraes et al. (2010) (RP = -34.6109 + 257.956 × ADG - 17.01 × RE), Silva et al. (2002a) (RP = -39.0169 + 200.638 × ADG + 0.4166 × RE),

Table 3 - Protein net requirements for gain (g/kgEBWg/day) of animals from different genetic groups and together due to the different body weights (BW)

BW (kg)	Nellore[1]	Nellore × Angus[2]	Nellore × Simmental[3]	Combined[4]
250	153.51	156.70	157.03	156.12
300	152.09	155.44	155.00	154.63
350	150.90	154.38	153.30	153.39
400	149.88	153.46	151.84	152.33
450	148.98	152.66	150.57	151.39

[1] NE: $EBW = 0.91 \times BWF$ / $NEg = 0.213 \times 0.949 \times EBW^{-0.051}$.
[2] NA: $EBW = 0.90 \times BWF$ / $NEg = 0.209 \times 0.956 \times EBW^{-0.045}$.
[3] NS: $EBW = 0.91 \times BWF$ / $NEg = 0.249 \times 0.929 \times EBW^{-0.072}$.
[4] Combined: $EBW = 0.91 \times BWF$; $NEg = 0.219 \times 0.948 \times EBW^{-0.052}$.
NE - Nellore; NA - Nellore × Angus; NS - Nellore × Simmental; EBW - empty body weight; Neg - net energy gain; BWF - body weight at fasting.

Véras et al. (2000) (RP = 0.416321 + 215.3456 × ADG - 14.135 × RE) and the NRC (2000) (PR = ADG × (268 - (29.4 (RE/ADG)) the values 152 , 75, 163.35, 157.10 and 145.99 were obtained, respectively. Equations proposed by the aforementioned authors have been generated mostly from experiments on males; it is coherent that net requirements of protein for gain were higher than those found in this experiment. It is noteworthy that the comparison with these authors was necessary due to the lack of studies on requirements of females.

Net requirements of protein for gain are dependent on body composition, varying with fat content and fat-free dry matter. Thus, it is clear why net requirements of protein for gain are higher for males than for females. According to Berg & Butterfield (1976), males deposit more lean tissue than females at the same age. Using the equation obtained in this study to estimate protein net requirements for gain and basing on the equations described by Souza et al. (2012) to estimate the retained energy by these heifers (RE (Mcal/day) = $0.0703 \times EBW^{0.75} \times EBWg^{1.128}$), accounting for 3.88 g/kg $EBW^{0.75}$/day metabolizable protein requirement for maintenance and considering 37.40% efficiency obtained by the regression between protein retained (g/$EBW^{0.75}$/day) and metabolizable protein intake (g/$EBW^{0.75}$/day), the net requirements of protein, metabolizable protein and total metabolizable protein (maintenance + gain) for heifers at different weights and different growth rates can be calculated (Table 4).

Requirements of net and metabolizable protein for gain are reduced with increasing body weight and incremented with the increased average daily gains (Table 4). This behavior reflects the decline of muscle development when animals approach the weight at maturity (Moraes et al., 2010). However, total metabolizable protein requirements are increased with increasing body weight, once maintenance requirements increase with the animal weight (Paulino et al., 2004).

From the metabolizable protein requirements (Table 4) and using the protocol of the NRC (2000) for conversion of total requirements of metabolizable protein in crude protein requirements, the daily requirements of protein, degradable protein in the rumen and undegradable protein in the rumen were calculated. For this calculation, dry matter intake was estimated by the equation proposed by Valadares Filho et al. (2006): $-1.4105 + 0.0171 \times ABW + 5.4125 \times ADG - 1.8691 \times ADG^2$, where ABW = average body weight (kg) and ADG = average daily gain (kg/day), and assuming a diet with 70% TDN (Table 5).

As body weight increased the daily requirements of non-degradable protein in the rumen to supply the total crude protein requirements lowered (Table 5). A similar result was found by Paulino et al. (2004). Thus, according to Silva et al. (2002b), heavier animals in the finishing stage can receive higher levels of non-protein nitrogen.

Silva et al. (2002a), working on a combined data analysis from 14 experiments conducted in Brazil reported that for Dutch and zebu animals weighing over 400 kg, the amount of degradable protein in the rumen supplied by a diet with 72% TDN and assuming that a 2.4% BW intake was sufficient to meet the total requirement of crude protein.

Lana et al. (1992), working on Nellore animals and crossed European × Zebu weighing 300 kg had their crude protein requirement met only by the degradable protein in the rumen.

Table 4 - Net requirements of protein, metabolizable protein for gain and total metabolizable protein (gain + maintenance) for animals with different body weights and average daily gains of 0.5, 1.0 and 1.5 kg/day

Weight gain, kg/day	Body weight, kg				
	250	300	350	400	450
	Protein net requirement for gain, g/day				
0.5	70.19	67.46	64.84	62.32	59.87
1.0	136.93	130.96	125.23	119.71	114.36
1.5	202.13	192.70	183.66	174.93	166.48
	Metabolizable protein requirement for gain, g/day				
0.5	187.68	180.38	173.37	166.62	160.07
1.0	366.11	350.15	334.85	320.08	305.77
1.5	540.46	515.25	491.07	467.74	445.13
	Total metabolizable protein requirement (maintenance + gain), g/day				
0.5	414.96	440.96	465.90	489.96	513.27
1,0	593.39	610.74	627.37	643.42	658.97
1,5	767.75	775.84	783.59	791.08	798.33

EBW - 0.91 × BWF; EBWg = 0.90 × ADG; RE = $0.0703 \times EBW^{0.75} \times EBWg^{1.128}$; NPg = 197.40 × EBWg – 11.14 × RE; $_mMP$ = 3.88g/$EBW^{0.75}$/day; Use efficiency of metabolizable protein for gain = 37.40%.
EBW - empty body weight; BWF - body weight at fasting; ADG - average daily gain; RE - retained energy; EBWg - empty body weight gain; NPg - net protein for gain; $_mMP$ = metabolizable protein requirement for maintenance.

Table 5 - Total requirements (maintenance + gain) of degradable protein in the rumen, non-degradable protein and crude protein for animals with different body weights and daily gains of 0.5, 1.0 and 1.5 kg/day

Weight gain kg/day	Body weight, kg									
	250		300		350		400		450	
	Degradable protein in the rumen									
	g/day	%CP	g/day	%CP	g/day	%CP	g/day	%CP	g/day	%CP
0.5	515.50	74.58	601.87	79.96	688.23	84.68	774.59	88.86	860.96	92.60
1.0	647.26	67.54	733.63	72.71	819.99	77.45	906.35	81.83	992.72	85.88
1.5	684.62	57.59	770.99	62.79	857.35	67.70	943.71	72.33	1030.08	76.72
	Non-degradable protein in the rumen									
	g/day	%CP	g/day	%CP	g/day	%CP	g/day	%CP	g/day	%CP
0.5	175.75	25.42	150.80	20.04	124.51	15.32	97.12	11.14	68.81	7.40
1.0	311.13	32.46	275.36	27.29	238.69	22.55	201.30	18.17	163.28	14.12
1.5	504.22	42.41	456.87	37.21	409.11	32.30	361.01	27.67	312.63	23.28
	Crude protein									
	g/dia	%DM	g/day	%DM	g/day	%DM	g/day	%DM	g/day	%DM
0.5	691.25	13.54	752.66	12.63	812.74	11.93	871.72	11.37	929.77	10.91
1.0	958.39	14.96	1008.98	13.89	1058.68	13.04	1107.65	12.34	1156.00	11.76
1.5	1188.84	17.54	1227.86	16.09	1266.46	14.92	1304.73	13.97	1342.70	13.17

EBW = 0.91 × BWF; EBWg = 0.90 × ADG; RE = 0.0703 × $EBW^{0.75}$ × $EBWg^{1.128}$; NPg = 197.40 × EBWg – 11.14 × RE; mMP = 3.88g/$EBW^{0.75}$/day; Use efficiency of metabolizable protein to gain = 37.40%; DMI = – 1.4105 + 0.0171 × ABW + 5.4125 × ADG – 1.8691 × ADG^2; Diet with 70% NDT; RDP and RNDP estimated by the protocol of the NRC (2000).
CP - crude protein; DM - dry matter; EBW - empty body weight; BWF - body weight at fasting; EBWg - empty body weight gain; ADG - average daily gain; NPg - net protein for gain; RE - retained energy; $_m$MP - metabolizable protein requirement for maintenance; DMI - dry matter intake; ABW - Average body weight; RDP = rumen digestible protein; RNDP - rumen non-digestible protein.

Participation of degradable protein in the rumen is reduced and non-degradable protein in the rumen is incremented with the increased average daily gain (Table 5), this suggests that the increase in growth rate of heifers results in greater participation of non-degradable protein in the rumen in the diet. Overall, the demand for crude protein ranged from 10.99 to 17.63% in DM, this result is slightly higher than the values from 9.58 to 14.4% recommended in the literature (Valadares Filho et al., 2006; Galyean, 1996). However, it should be noted that this difference was due to the low use efficiency of metabolizable protein (34.31%) found in this study.

Net requirements of protein for maintenance were obtained by regression of the retained protein (g/$EBW^{0.75}$/day) as function of metabolizable protein intake (g/$EBW^{0.75}$/day). Net requirements of protein for maintenance are represented by the model intercept. The slope represents the conversion efficiency of metabolizable protein to net protein (Figure 2).

No significant effect of genetic groups on the model coefficients was observed (P>0.05) with 1.07 g/$EBW^{0.75}$/day net protein requirement for maintenance. This value is lower than the 2.69 and 2.30 g/$EBW^{0.75}$/day found by Valadares Filho et al. (2006) and AFRC (1993) but closer to 1.74 g/$EBW^{0.75}$/day found by Chizzotti et al. (2008), working in Brazil on crossbred F_1 Nellore × Angus.

The use efficiency of metabolizable protein for gain was 37.40%; this value is much lower than the 49.2% recommended by NRC (2000). This difference is consistent, since the efficiency of protein utilization is dependent on its amino acid composition and the biologically available amount, directly influenced by the quality of the feed used in the diet. The quality of feed used by the aforementioned committee in feed formulation is different from those used in the tropics, in addition to the use of anabolic agents.

Through the regression of metabolizable protein intake (g/day) as function of average daily gain (kg/day) of animal performance and maintenance, metabolizable protein requirements for maintenance were obtained. Models identity test indicated no significant difference (P> 0.05) between genetic groups on such requirement. Therefore, a combined equation for all groups was generated (Figure 3). Metabolizable protein requirements for maintenance were

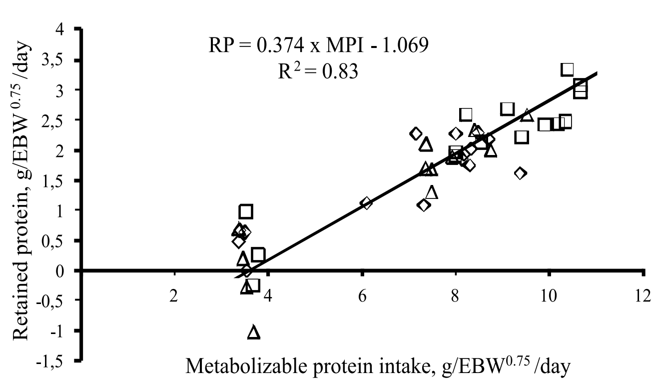

Figure 2 - Ratio between retained protein (RP) and metabolizable protein intake (mPI).

obtained by dividing the intercept of the equation described above by the average metabolic weight of animals, so the metabolizable protein requirement for maintenance was 3.88 g/EBW$^{0.75}$/day (269.47/69.44). This value is in agreement with those found in the literature, ranging from 3.25 to 4.0 g/BW$^{0.75}$/day (INRA, 1988; NRC, 2000; Valadares Filho et al., 2006).

The net requirements of protein and metabolizable protein requirements for maintenance increased with higher body weight (Table 6), which was expected once maintenance requirements are function of body weight.

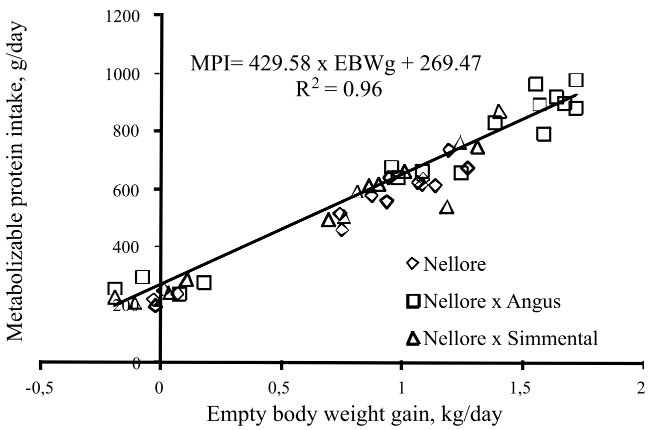

Figure 3 - Ratio between metabolizable protein intake (mPI) and gain of empty body weight (EBW).

Table 6 - Net requirements of protein and metabolizable protein for maintenance of Nellore, Angus × Nellore and Simmental × Nellore

Body weight,kg	Net protein, g/day	Metabolizable protein, g/day
250	62.68	227.28
300	71.86	260.59
350	80.67	292.53
400	89.17	323.34
450	97.40	353.20

EBW = 0.91 × BWF; NP_m = 1.07 g/EBW$^{0.75}$/day; $_m$MP = 3.88g/EBW$^{0.75}$/day. EBW = empty body weight; BWF = body weight at fasting; NPm = net protein for maintenance; $_m$MP = metabolizable protein requirement for maintenance.

Conclusions

Using the combined equation NPg = 197.40 × EBW – 11.14 × RE to predict net requirements of protein for weight gain of Nellore, F_1 Nellore × Angus and F_1 Simmental × Nellore females is recommended. Net requirements of protein for maintenance of Nellore, F_1 Nellore × Angus and F_1 Nellore × Simmental females are 1.07 g/EBW$^{0.75}$/day and metabolizable protein for maintenance is 3.88 g/EBW$^{0.75}$/day. The use efficiency of metabolizable protein for gain in all genetic groups is 37.04%.

References

AGRICULTURAL AND FOOD REASERCH COUNCIL – AFRC. **Energy and protein requirements of ruminants**. Wallingford: Agricultural and Food Research Council. CAB International, 1993. 159p.

AGRICULTURAL RESEARCH COUNCIL – ARC. **The nutrient requirements of ruminants livestock.** London: 1980. 351p.

BACKES, A.A.; SANCHEZ, L.M.B.; GONÇALVES, M.B.F. et al. Composição corporal e exigências líquidas de energia e proteína para ganho de peso de novilhos santa gertrudis **Revista Brasileira de Zootecnia**, v.31, n.6, p.2307-2313, 2002.

BALDWIN, R.L. **Modeling ruminant digestion and metabolism**. London: Chapman and Hall, 1995. 592p.

BERG, R.T.; BUTTERFIELD, R.M. **New concepts of cattle growth**. New York: Sidney University, 1976. 240p.

CHIZZOTTI, M.L.; TEDESCHI, L.O.; VALDARES 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.7, p.1588-1597, 2008.

FREITAS, J.A.; QUEIROZ, A.C.; DUTRA, A.R. et al. Eficiência de utilização da energia metabolizável em bovinos Nellore puros e cruzados submetidos a quatro níveis de concentrado na ração. **Revista Brasileira de Zootecnia**, v.35, n.3, p.894-901, 2006.

FULLER, W.A. **Measurement error models**. New York: John Wiley and Sons, 1987. 440p.

GALYEAN, M.L. Protein levels in beef cattle finishing diets: industry application. University research and systems results. **Journal of Animal Science**, v.74, p.2860-2879, 1996.

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

GOULART, R.S.; ALENCAR, M.M.; POTT, E.B. et al. Composição corporal e exigências líquidas de proteína e energia de bovinos de quatro grupos genéticos terminados em confinamento. **Revista Brasileira de Zootecnia**, v.37, n.5, p.926-935, 2008.

HALL, M.B. **Calculation of non-structural carbohydrate content of feeds that contain non-protein nitrogen**. Gainesville: University of Florida, 2000. p.A-25 (Bulletin, 339).

HALL, M.B.; HOOVER, W.H.; JENNINGS, J.P. et al. A Method for partitioning neutral detergent soluble carbohydrates. **Journal Science Food Agriculture**, v.79, n.9, p.2079-2086, 1999.

INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE – INRA. **Tables de L´alimentacion des bovins ovins e caprins**. Paris: Institut National de La Recherche Agronomique, 1988. 192p.

LANA, R.P.; FONTES, C.A.A.; PERON, A.J. et al. Composição corporal e exigências de energia, proteína e macroelementos minerais (Ca, P, Mg, Na e K) de novilhos de cinco grupos raciais em confinamento. 1. Conteúdo corporal e do ganho de peso em gordura, proteína e energia. **Revista Brasileira de Zootecnia**, v.21, n.3, p.518-527, 1992.

MARCONDES, M.I.; VALADARES FILHO, S.C.; OLIVEIRA, I.M. et al. Exigências de proteína de animais Nelore puros e cruzados com as raças Angus e Simental. **Revista Brasileira de Zootecnia,** v.40, n.10, p.2235-2243, 2011.

MORAES, E.H.B.K.; PAULINO, M.F.; MORAES, K.A.K. et al. Exigências de proteína de bovinos anelorados em pastejo. **Revista Brasileira de Zootecnia**, v.39, n.3, p.601-607, 2010.

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

NATIONAL RESEARCH COUNCIL - NRC. **Nutrient requirements of dairy cattle.** 7.ed. Washinton, D.C.: National Academic Press, 2001. 381p.

OWENS, F.N.; DUBESKI, P.; HANSON, C.F. Factors that alter growth and development of ruminants. **Journal of Animal Science**, v.71, p.3138, 1993.

PAULINO, P.V.R.; COSTA, M.A.L.; VALADARES FILHO, S.C. et al. Exigências nutricionais de zebuínos: Proteína. **Revista Brasileira de Zootecnia**, v.33, n.3, p.759-769, 2004.

PAULINO, P.V.R.; VALADARES FILHO, S.C.; DETMANN, E. et al. Deposição de tecidos e componentes químicos corporais em bovinos Nellore de diferentes classes sexuais. **Revista Brasileira de Zootecnia,** v.38, n.12, p.2516-2524, 2009.

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). 3.ed. Viçosa, MG: Imprensa Universitária, Universidade Federal de Viçosa, 2002. 165p.

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**, v31, n.2, p.776-792, 2002a.

SILVA, F.F.; VALADARES FILHO, S.C.; ÍTAVO, L.C.V. et al. Composição corporal e requisitos energéticos e protéicos de bovinos Nellore, não castrados, alimentados com rações contendo diferentes níveis de concentrado e proteína. **Revista Brasileira de Zootecnia**, v31, n.1, p.503-513, 2002b.

SOUZA, E.J.O.; VALADARES FILHO, S.C.; GUIM, A. et al. Energy nutritional requirements for females of Nellore, Nellore × Angus and Nellore × Simmental fed on two forage:concentrate ratios. **Revista Brasileira de Zootecnia**, v.41, n.3, p.753-761, 2012.

VALADARES FILHO, S.C.; MARCONDES, M.I.; CHIZZOTTI, M.L. et al. **Exigências nutricionais de zebuínos puros e cruzados – BR CORTE**. 2.ed. Viçosa, MG: UFV, Suprema Gráfica Ltda., 2010. 193p.

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

VÉRAS, A.S.C.; VALADARES FILHO, S.C.; SILVA, J.F.C. et al. Composição corporal e requisitos energéticos e protéicos de bovines Nellore, não-castrados, alimentados com rações contendo diferentes níveis de concentrado. **Revista Brasileira de Zootecnia,** v.29, n.8, p.2379-2389, 2000.

WEISS, W.P. Energy prediction equations for ruminant feeds. In: CORNELL NUTRITION CONFERENCE FOR FEED MANUFACTURERS, 1999, Rochester. **Proceedings...** Rochester: New York State College of Agriculture & Life Sciences, Cornell University, 1999. p.176-185.