PROTEIN REQUIREMENTS OF ZEBU BEEF CATTLE

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INTRODUCTION

Protein is one of the most important essential nutrients; it is involved in many vital functions in the body, such as growth and tissue repair, enzyme catalysis, transport and storage, coordinated movement, mechanical support, immunological protection, generation and transmission of nerve impulses, and control of metabolism, growth and cellular differentiation. Therefore, ensure adequate supply of protein to animals involve provide an essential nutrient to maintain the homeostasis, allowing the efficient production of beef. Ruminants have peculiarities in terms of protein nutrition; their protein demands are met through amino acids absorbed by the small intestine as in any other animal, however a large portion of digestible protein (50 to 80%) comes from microbial protein synthesized in the rumen (Bach et al., 2005).

Despite its importance, true protein is the most expensive nutrient alone in beef cattle diets, and its inclusion in an unbalanced manner results in increased production costs (Cavalcante et al., 2005). Countless studies have been conducted to evaluate the replacement of true protein by alternative and lower cost sources, like urea, in attempt to meet the animal's demands as economically as possible (Magalhães et al., 2005). In addition to its high cost, an excess of dietary protein results in a reduction in fertility (Elrod and Butler, 1993) and increased urea excretion in urine, which, when converted to ammonia, turns into a compound that can become a serious pollutant, especially in fragile ecosystems (Klemesrud et al., 2000). Consequently, there is a greatly societal pressure on animal production systems, especially intensive systems, to adopt procedures to reduce the environmental impact. In addition, the appropriate formulation of diets, meeting exactly the protein needs of animals, is one of the ways to ensure that excess urea is not excreted into the environment (Todd et al., 2006). Evidently, such procedures can only be taken when the exact protein requirements of animals are known, categorized into maintenance, growth, gestation and lactation beef cattle protein requirements (NRC, 2000).

PROTEIN REQUIREMENTS FOR MAINTENANCE

The cattle demand for maintenace protein is equivalent to the fecal and urinary metabolic N losses, in addition to the protein lost by scurf. Wilkerson et al. (1993) found that the daily metabolizable protein requirement for maintenance (MP_m) was 3.8 g/$BW^{0.75}$, which has been adopted by the NRC (2000). This protein requirement for maintenance was obtained from 45 individual observations involving various protein sources, with the number of animals per protein source varying from 3 to 30. The value 3.8 was obtained by the division of the intercept (242) of the regression equation for metabolizable protein intake (g/day) as a function of the weight gain (kg/day) of the animals by the mean metabolic live weight of animals (63.44) in the database used.

The NRC (2000) preferred to adopt the value reported by Wilkerson et al. (1993) because it was determined using animal growth data. This is in contrast to the values of 3.25 g/$EBW^{0.75}$/day and 3.52 g/$BW^{0.75}$/day obtained by the French system (INRA, 1988) and by Smuts (1935), respectively, which were derived from experiments involving nitrogen balance, although the nitrogen balance study of

Susmel et al. (1993) corroborate the value of 3.8 g MP/BW$^{0.75}$. However, the AFRC (1993) assumes that the daily metabolizable protein requirement for maintenance is 2.30 g/ BW$^{0.75}$, based on the sum of basal endogenous nitrogen requirements and other losses by scurf and skin.

There are also a small number of Brazilian studies involving the measurement of protein requirements for maintenance of Zebu cattle. Ezequiel (1987) found daily metabolizable protein requirements for maintenance of 1.72 and 4.28 g/BW$^{0.75}$ for Nellore and Holstein calves, respectively. Valadares et al. (1997) calculated the daily metabolizable protein requirements for maintenance in 4.13 g/BW$^{0.75}$, taking into account the endogenous fecal losses, estimated by the regression of digestible nitrogen intake on nitrogen intake, and the endogenous urine N losses, obtained by the regression of the urinary nitrogen on the nitrogen intake.

In the first edition of BR-CORTE, the net protein requirement for maintenance of 2.69 g/BW$^{0.75}$, obtained by Véras (2006), was adopted. The authors evaluated bulls, steers and heifers fed one of four levels of crude protein (7; 10; 13 and 15%) and did not find effect of gender on the requirement (Figure 1). The net protein requirements for maintenance were obtained as the intercept of the regression (0.4313 × 6.25 = 2.69) of retained nitrogen on nitrogen intake.

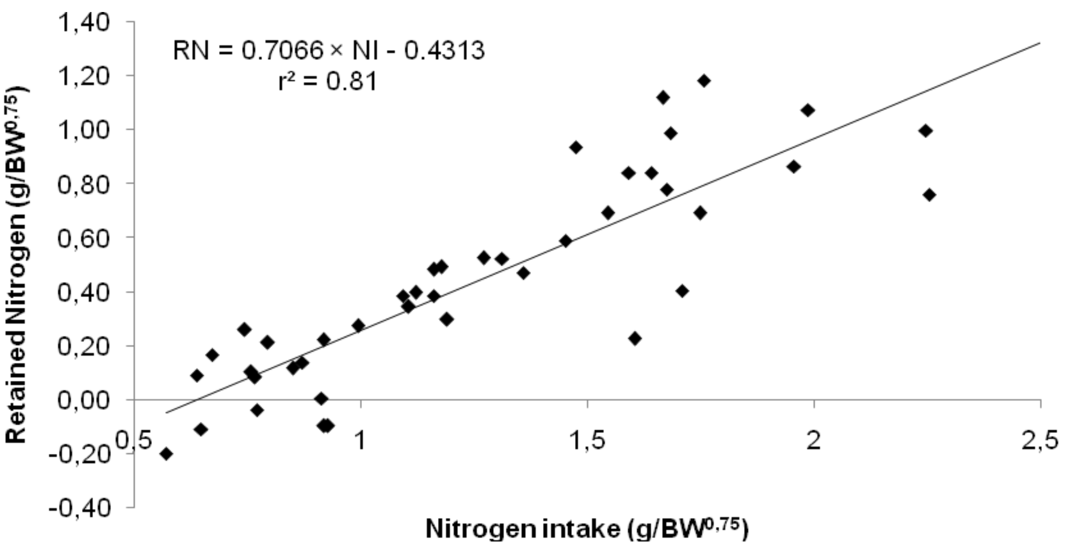

Figure 1 - Relationship between retained nitrogen (RN) and nitrogen intake (NI), expressed in (g/kg$^{0.75}$). Adapted from Véras (2006).

To convert the net protein requirements to metabolizable protein requirements for maintenance, a factor of 0.667 was used, which was obtained through the relationship between retained nitrogen and absorbed nitrogen (Figure 2), and was very similar to the value of 0.67, which is recommended by the NRC (1985). Using this efficiency and assuming the net protein requirement of 2.69 g of net protein /BW$^{0.75}$ for maintenance, the daily metabolizable protein requirement was calculated as 4.03 g/BW$^{0.75}$, which is similar to the recommended amount of 3.8g/BW$^{0.75}$ (NRC, 2000). Therefore, the BR-CORTE (Valadares Filho et al., 2006) recommended the use of the value 4 g of MP/BW$^{0.75}$ as the MP requirements for maintenance (MP_m).

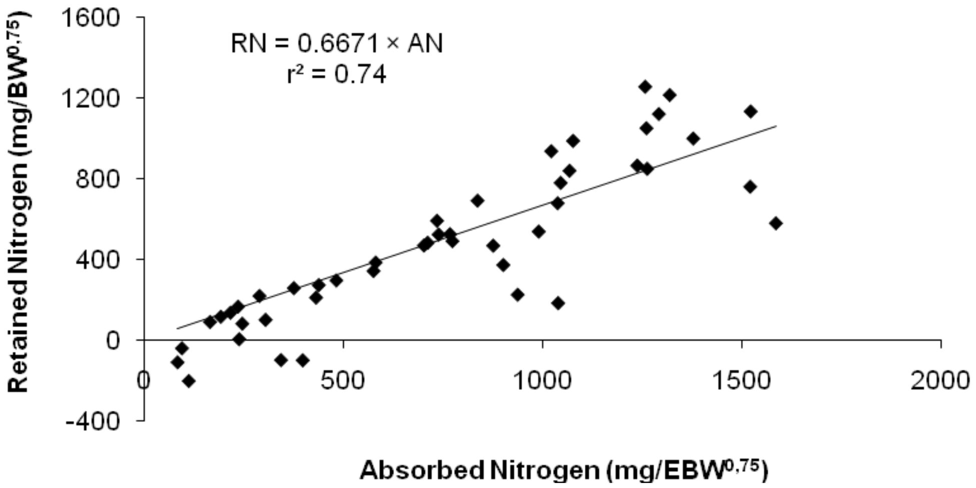

Figure 2 - Relationship between retained nitrogen (RN) and absorbed nitrogen (AN). Adapted from Véras (2006).

Work with crude protein intake, can lead to various estimation errors, as it does not considerer the biological value of crude protein or the efficiency of microbial crude protein synthesis (MCP) per kg of digestible dry matter. Therefore, it would be more appropriate to work with metabolizable protein intake, which accounts for the protein that will be available in the small intestine. From the efficiency recommended in chapter 2, of 120 g of MCP/kg of TDN, it was possible to convert the crude protein intake from the BR-CORTE database in metabolizable protein intake and correlate it with the average daily gain, as suggested by the NRC (2000). In that manner, the MP_m requirements would be the point in which the daily gain would be null (Figure 3).

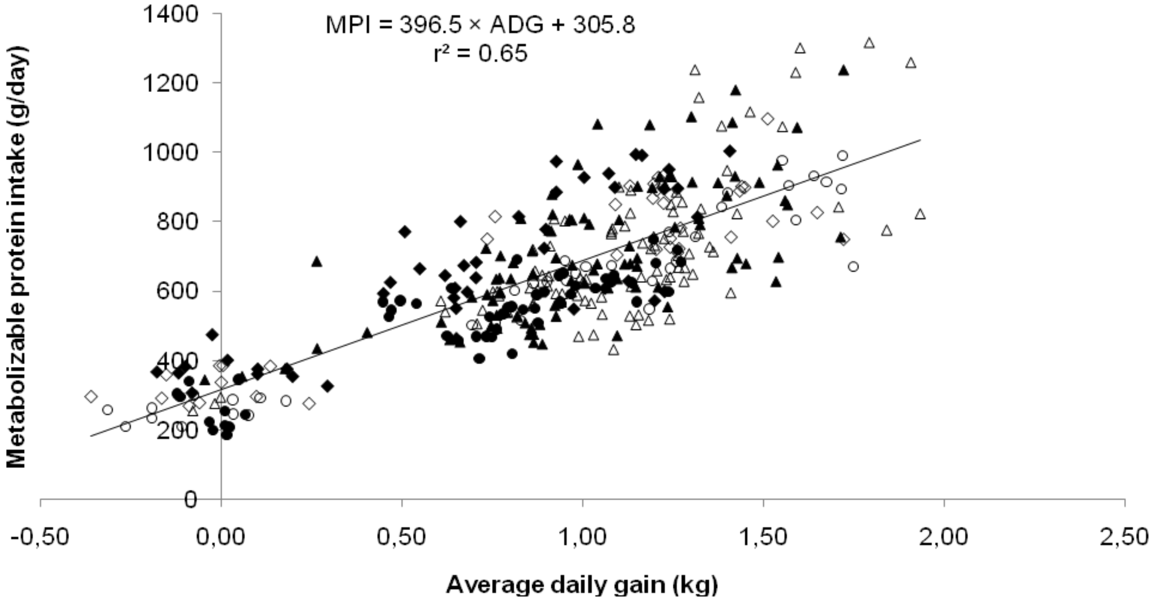

Figure 3 - Relationship between metabolizable protein intake (MPI) and average daily gain (ADG). The symbols represent data from bulls (▲, Δ), steers (◊,♦), and heifers(○, ●). Solid points represent Nellore cattle and open points represent crossbred *Bos indicus* × *Bos taurus* cattle.

Evaluating the relationship between metabolizable protein intake (MPI) and average daily weight gain (ADG), it was observed no effect of breed or gender (P>0.05), which enabled the formulation of a overall equation:

MPI = 305.8 + 396.5 × ADG

where MPI is the metabolizable protein intake (g/day), and ADG is the average daily gain (kg/day).

According to the proposal of the NRC (2000), the MP_m requirements would be obtained by dividing the intercept by the average metabolic weight of the animals used to generate the equation. Thus, dividing 305.8 by the average metabolic weight of the cattle evaluated, an MP_m requirement of 4.14 g of MP/$EBW^{0.75}$ was obtained, which is close to 3.81 g of MP/$BW^{0.75}$.

Another option to estimate MP_m requirements would be the use of empty body weight gain (EBG) instead of ADG, since EBG minimizes errors caused by gut fill effects.

When MPI was correlated with EBG, there was an effect of breed on the protein requirements for body gain (Figure 4); however, there was no effect of breed or gender on the intercept, suggesting that there are no differences between them.

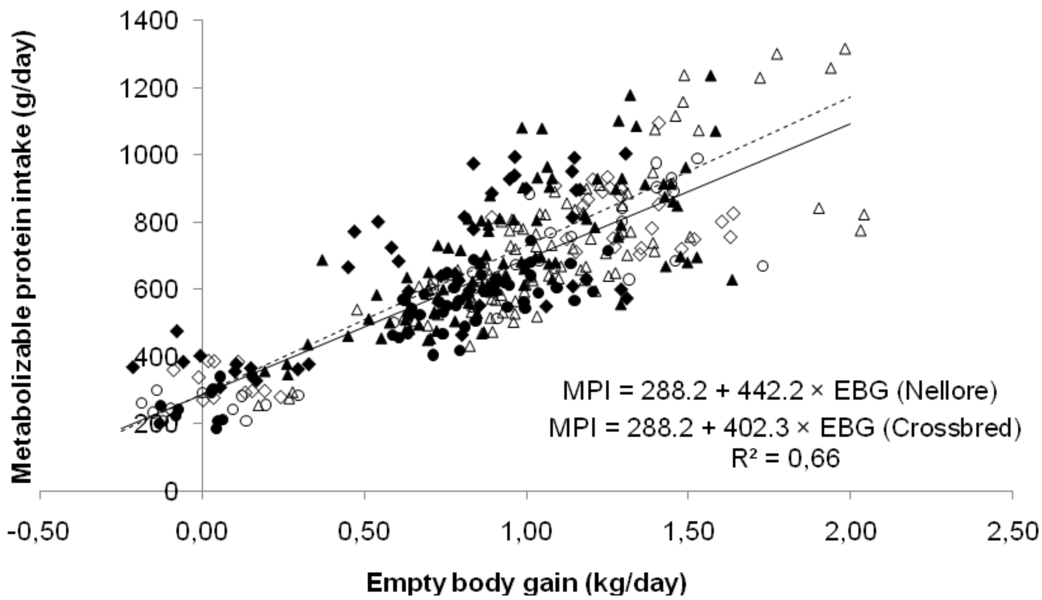

Figure 4 - Relationship between metabolizable protein intake (MPI) and empty weight gain (EBG). The symbols represent data from bulls (▲, Δ), steers (◊,♦), and heifers (○, ●). Solid points represent Nellore animals and open points represent crossbred *Bos indicus* × *Bos taurus* animals. The solid line represents Nellore cattle and the dotted line represents crossbred animals.

The effect of breed on MP requirements for empty weight gain will be discussed later. The equations developed were:

Nellore MPI = 288.2 + 442.4 × EBG
Crossbred MPI = 288.2 + 402.3 × EBG

where MPI is the metabolizable protein intake (g/day), and EBG is the empty body weight gain (kg/day).

As the intercept was the same for both purebred and crossbred, the MP_m requirements can be obtained by dividing the value 288.2 by the average metabolic empty body weight of the animals, thus yielding a requirement of 3.91 g of $MP/EBW^{0.75}$.

The two models generated to estimate MP_m produced values that were very similar to those proposed in the last version of BR-CORTE (4.0 $g/BW^{0.75}$). On average, the MP_m requirements using the models described above were 4.03 $g/EBW^{0.75}$ [(3.91 + 4.14)/2 = 4.03 g of $MP/EBW^{0.75}$) or 3.71 $g/BW^{0.75}$. Therefore, we propose keeping the value of 4.0 g of $MP/BW^{0.75}$ for the MP_m requirement.

The database of grazing animals showed that under these conditions, there is an increase in MP_m requirements. Only the effects of ADG on MPI were tested, since the analysis of the EBG did not produce consistent results (Figure 5).

The equation developed was:

$$MPI = 354.28 + 261.55 \times ADG$$

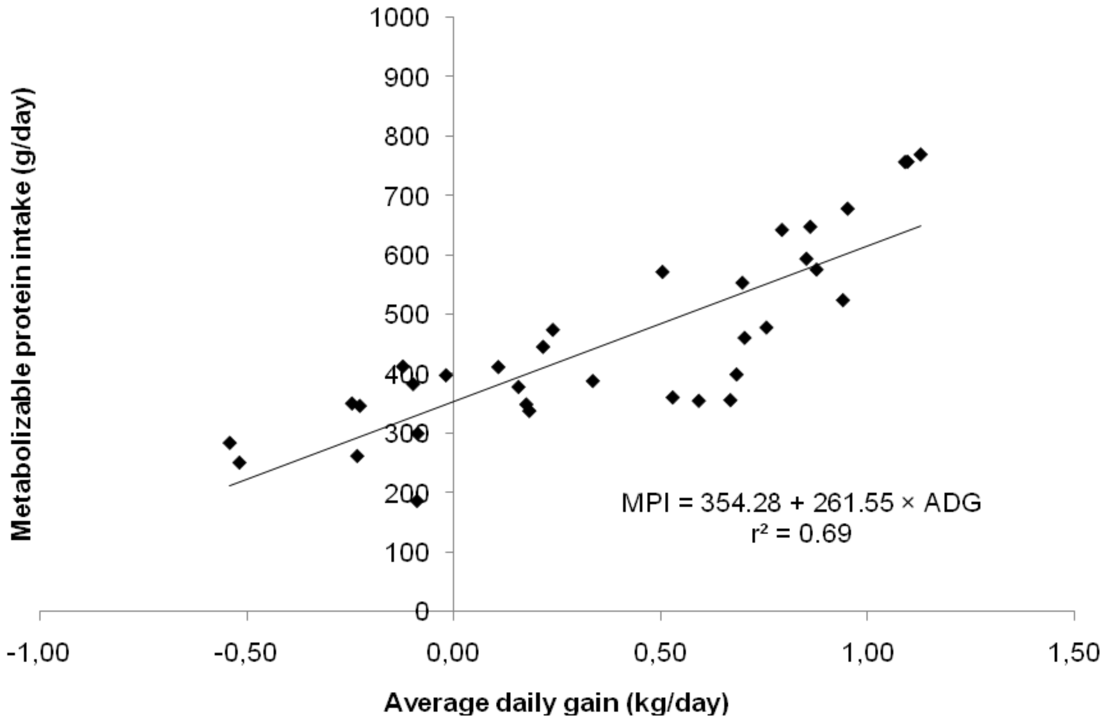

Figure 5 - Relationship between metabolizable protein intake and average daily gain (ADG) of grazing animals.

Thus, by dividing the intercept by the average metabolic weight of the animals used to generate the equation, the MP_m requirements of 4.87 $g/EBW^{0.75}$, or 4.5 $g/BW^{0.75}$ were obtained. Therefore, pasture-finished cattle had a metabolizable protein requirement that was 12.3% greater than that for those in feedlot.

The results obtained for MP_m are consistent with those found for ME_m requirements, in which animals under pasture conditions had 11% more demand than those in feedlot. This higher MP_m requirement is probably due to the higher daily voluntary activities of animals under pasture conditions.

PROTEIN REQUIREMENTS FOR WEIGHT GAIN

The net protein requirements for growth and finishing are dependent on the content of fat-free dry matter on weight gain. Therefore, its determination is dependent on the measurement of body composition of the animals, thus varying with weight, rate of weight gain, breed, gender, dietary effects and nutritional management (Fox and Black, 1984). Due to this variation in the composition of gain, it is observed that the net protein requirements for gain are greater in bulls than in steers and in late maturing rather than early maturing cattle (Geay, 1984). This is because bulls deposit more lean tissue than steers (Vanderwert et al., 1985) that in turn, deposit more than heifers of the same age (Berg and Butterfield, 1976).

In the first version of BR-CORTE, the net protein requirements for gain (or retained protein) were estimated from regression equations of retained protein (NP_g) as a function of energy retained (NE_g) and the average shrunk weight gain (ADG). The equations obtained for each gender, independently, were:

Bulls	$NP_g = 26.46 - 9.38 \times NE_g + 183.49 \times ADG$
Steers	$NP_g = 1.42 - 12.29 \times NE_g + 180.03 \times ADG$
Heifers	$NP_g = 26.81 - 16.48 \times NE_g + 163.87 \times ADG$

where NP_g are the net protein requirements for gain (g/day), NE_g is the energy retained (Mcal/day), and ADG is the average daily gain (kg/day).

The NRC (2000) suggests another model to estimate the net protein requirements for gain: $NP_g = ADG \times [268 - 29.4 \times (NE_g / ADG)]$, in which the protein gain is not only related to the energy retained, but also to the proportion of energy in gain. In this edition, the BR-CORTE suggests using a model similar to that described by the NRC (2000), but substituting ADG by empty body weight gain (EBG).

The new proposal for net protein requirements for weight gain (NP_g), using the updated BR-CORTE database, presented breed and gender effects on the model; however, there were no differences between steers or heifers, regardless of breed. The models obtained were:

Nellore cattle	
Bulls	$NP_g = 238.79 \times EBG - 15.68 \times NE_g$
Steers and heifers	$NP_g = 163.73 \times EBG - 4.65 \times NE_g$
Crossbred cattle	
Bulls	$NP_g = 219.43 \times EBG - 15.01 \times NE_g$
Steers and heifers	$NP_g = 188.71 \times EBG - 7.67 \times NE_g$

where NP_g are the net protein requirements for weight gain (g/day), NE_g is the energy retained (Mcal/day), and EBG is the empty body weight gain (kg/day).

The equations indicate greater EBG coefficients for bulls in relation to steers and heifers, showing a strong effect of the level of circulating testosterone on protein deposition in the gain. This implies that bulls have a greater growth potential, but also greater NP_g requirements. The equations also show that this effect is reduced for crossbred animals in relation to Nellore cattle.

Using a 300-kg Nelore animal with an average gain of 1 kg/day as an example, net protein requirements for gain were calculated as 171.21 g/day for bulls and 133.28 g/day [(134.44+132.12)/2] for steers and heifers. For a crossbred (*Bos indicus* × *Bos taurus*) cattle, the requirements were 162.44 for bulls and 149.81 g/day [(151.69+147.93)/2] for steers and heifers.

For animals under pasture conditions, an overall equation was obtained for bulls and steers:

$$NP_g = 221.39 \times EBG - 6.61 \times NE_g$$

It is possible that the greater value obtained for grazing animals is explained by their lower slaughter weights. Furthermore, the average metabolic weights of these cattle was lesser (71.78 kg) in relation to those in feedlot (79.73 kg), which may indicate that these animals were still in a phase of high protein and low fat depositions.

Taking the same 300-kg Nellore animal with an average gain of 1 kg/day as an example, the net protein requirements for gain were calculated as 195.50 g/day, suggesting that the requirements for gain, like the requirements for maintenance, are greater for animals on pasture conditions.

Efficiency of metabolizable protein utilization for gain

From the knowledge of the partial efficiency of metabolizable protein utilization for weight gain (*k*), the net protein requirements can be converted into metabolizable protein requirements, which encompass the digestible rumen undegradable crude protein intake and digestible true microbial protein, i.e., the amount of amino acids available for absorption in the small intestine.

The NRC (1984), based on a study of Zinn and Owens (1983), reported that the average biological value of amino acids absorbed by cattle is 66%. Based on this and other studies, the NRC (1985) adopted the values 0.5 and 0.65 for the efficiency of metabolizable protein utilization for weight gain (*k*), and these values also took into account the biological value of protein and the value of an ideal mixture of amino acids (Oldham, 1987). Oldham (1987) also suggested an efficiency of 0.85 for all physiological functions, as a value denoting the efficiency of conversion of an ideal mixture of amino acids. Because this does not happen in practice, the real efficiency is normally below this value.

The biological value of microbial protein is high due to the high quality of the amino acid mixture of this protein source, consequently the proportion of microbial protein in the total protein reaching the intestine can change the efficiency of utilization of metabolizable protein (NRC, 2000).

The French system (INRA, 1988) uses a variable *k* as body weight increases. Ainslie et al. (1993) and Wilkerson et al. (1993) confirmed this decreasing efficiency, endorsing the NRC (1996 and 2000) to adopt the equation developed by Ainslie et al. (1993) to estimate *k* for 150 to 300 kg cattle, as:

$$k = 83.4 - (0.114 \times EQEBW)$$

This equation predicts that a 150-kg animal has an efficiency of MP utilization for gain of 0.663, whereas a 300-kg animal would have an efficiency of 0.492. The data obtained by Ainslie et al. (1993) and Wilkerson et al. (1993) were acquired with weights varying from 150 to 300 kg, and as a result, the NRC (2000) uses this equation only for animals with EQEBW less than 300 kg. For greater weights, the NRC (2000) uses a fixed value of 0.492, from earlier publications (NRC, 1984), stressing that when animals reach weights close to 400 kg, the protein requirements for gain are low.

The British system (AFRC, 1993) calls the efficiency of utilization of an ideal mixture of amino acids, k_{aai}, and emphasizes that it is a characteristic of the animal.

However, this system recognizes that, in practice, lower values than the ideal efficiency have been found, and the practical value essentially depends on the quality of the mixture of amino acids in the digestible rumen undegradable crude protein intake (RUPd) and the ratio of RUPd and digestible true microbial protein that reaches the small intestine. The AFRC (1993) consider a fixed efficiency of MP utilization of 1.0 for maintenance, 0.59 for weight gain, 0.85 for gestation, 0.68 for lactation and 0.26 for wool production.

In Brazilian literature, only three studies present results for the efficiency of MP utilization for weight gain, obtained as being the slope of the regression of retained protein on MP intake. Marcondes et al. (2009) found a partial efficiency of MP utilization for gain of 50.18%, but Gionbelli (2010) established an efficiency of 42.07%. Marcondes et al. (2010) found a *k* of 37.51% based on the evaluation of Nellore and crossbreds of Nellore × Angus and Nellore × Simmental; according to the latter, the use of byproducts of the agricultural industry can reduce the quality of protein available in the small intestine, reducing *k*. This can be one of the reasons for lower efficiency values obtained under Brazilian conditions in relation to those normally found under other conditions (CSIRO, 2007; NRC, 2000; AFRC, 1993; INRA, 1988). Marcondes et al. (2009) and Gionbelli (2010) worked with crude protein levels greater than 12.5% in the DM of the diet, which can also explain the lower efficiencies found in these studies.

The previous version of BR-CORTE used the recommendations suggested by the NRC (2000) for *k*. In this edition, the value for *k* was taken as the slope of the regression of retained protein on MPI.

Evaluating the retained protein (RP) in relation to MPI (Figure 6), no effects of breed or gender were found on *k*, thus the overall model is:

RP = – 2.223 + 0.4691 × MPI where RP is the retained protein (g/EBW$^{0.75}$), and MPI is the metabolizable protein intake (g/EBW$^{0.75}$)

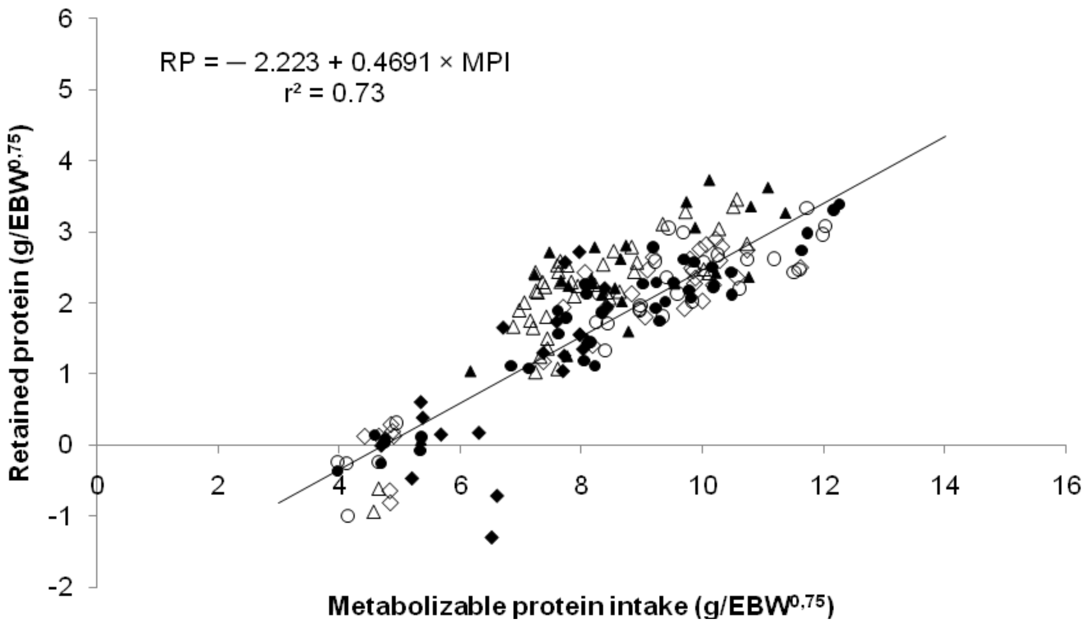

Figure 6 - Relationship between retained protein (RP) and metabolizable protein intake (MPI). The symbols represent data from bulls (▲, Δ), steers (◊,♦), and heifers (○, ●). Solid points represent Nellore cattle and open points represent crossbred *Bos indicus* × *Bos taurus* cattle.

The efficiency of MP utilization for weight gain is of 46.9% for pure and crossbred Zebu cattle; this value is similar to the value recommended by the NRC (2000), which was 49.2%.

Nevertheless, the majority of systems agrees that the use of a constant *k* does not represent the real efficiency of the animals (CSIRO, 2007; NRC, 2000; AFRC, 1993; INRA, 1988). However, as suggested by Oldham (1987), *k* seems to be more related to the type of MP than to the EQEBW, as suggested by the INRA (1988). Taking the studies used to estimate the equation shown in Figure 6 and estimating the average efficiency of each experiment, it was possible to correlate *k* with EQEBW.

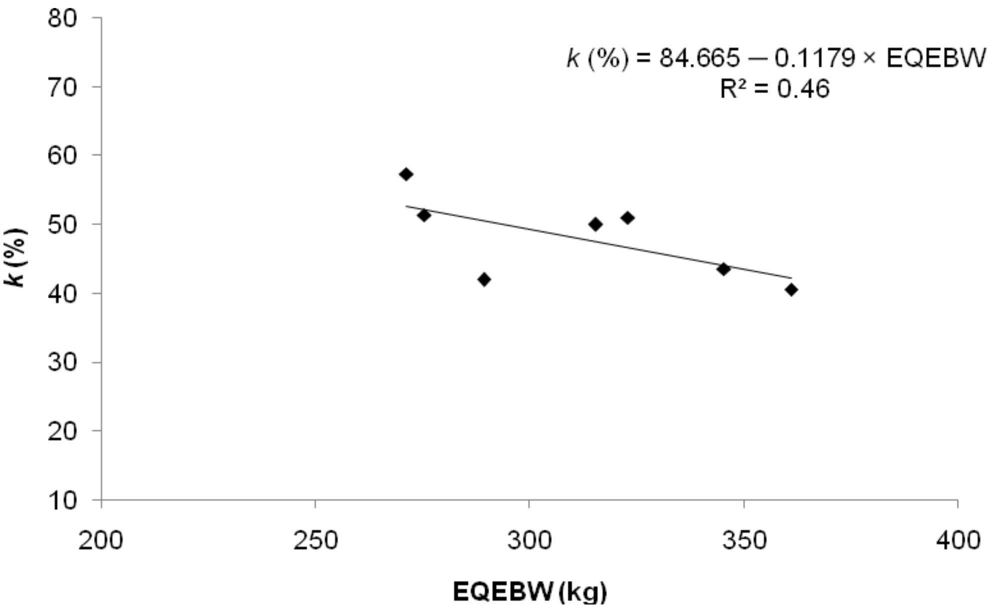

Figure 7 - Relationship between the partial efficiency of metabolizable protein use for gain (*k*) and the equivalent empty body weight (EQEBW).

The following equation was developed to estimate *k*:

$$k\ (\%) = 84.665 - 0.1179 \times EQEBW$$

where k is the efficiency of use of metobolizable protein and EQEBW is the equivalent empty body weight (kg).

The developed equation is similar to that suggested by the NRC (2000) for animals under 300 kg. However, animals up to 360 kg of EQEBW were used for these calculations.

Taking a 150-kg animal as an example, the equation above would predict an efficiency of metabolizable protein use of 68%, which is similar to the 67% suggested by the equation from NRC (2000). Increasing animal's weight there is a reduction in this efficiency. The NRC (2000) does not have efficiency data for animals over 300 kg, and therefore used a constant efficiency of 49.2% for animals heavier than 300 kg.

Considering that the database from BR-CORTE has cattle weighing up to 492 kg, the use of the equation described above is recommended for animals with a shrunk body weight lower or equal to 350 kg and a constant value of efficiency of 46.9% for animals over 350 kg. The shrunk body weight of 350 kg was adopted because when this weight was used to calculate the efficiency, a value of 46.9% was obtained. This value (46.9%) is equal to the value obtained by the slope of the regression of retained protein on the metabolizable protein intake.

The use of the same model to estimate *k* for cattle under pasture conditions did not produce satisfactory results, probably due to the sparseness of existing data and the difficulty of estimating the protein intake of animals under this condition. Therefore, it was decided that grazing animals would adopt the same efficiencies suggested for cattle in feedlot.

To obtain the RDP requirements of cattle under Brazilian conditions, the efficiency of microbial protein synthesis (MCP) of 120 g of MCP/kg of TDN intake was used. It was obtained from a compilation of Brazilian data and recommended in the second chapter of this publication. The efficiency of conversion of rumen degraded protein intake into microbial nitrogen was 90%, therefore the RDP requirements are calculated as 1.11 x MCP.

The TDN intake will be obtained from the conversion of net energy requirements for maintenance and weight gain, described in the energy chapter, for each gender, breed and raising system.

To calculate the RUP requirements, factors described by the NRC (2000) were adopted. We assumed that the microbial crude protein contains 80% of amino acids and a small intestinal digestibility of 80%. A fixed value of 80% was also used for the digestibility of RUP in the small intestine. However, there are values of intestinal digestion of crude protein of some feeds used in Brazil. These data are available in the Brazilian tables of feed composition for cattle (CQBAL 3.0), and can be accessed by www.ufv.br/cqbal for who wish to use variable values for the intestinal digestibility of RUP to calculate the RUP requirements.

PROTEIN REQUIREMENT TABLES

From the determination of net protein requirements for weight gain (NP_g), it was possible to derive a subsequent conversion into metabolizable protein (MP_g) requirements for gain. Tables 1 and 2 show the summary of all equations that were used for the estimation of protein requirements for Nellore and crossbred cattle of different genders, in this edition of BR-CORTE.

Tables 3 and 4 show, respectively, the net protein requirements for gain of Nellore purebred and crossbred, while their total requirements of metabolizable protein are shown in Tables 5 and 6, respectively.

Tables 7 and 8 show the RDP requirements for Nellore purebred and crossbred, respectively, of different gender, while their RUP requirements are shown in Tables 9 and 10, and the CP requirements are shown in Tables 11 and 12. In Table 13, the net protein requirements for gain are shown, as well as the total requirements of MP, RDP, RUP and CP for grazing Nellore cattle.

Table 1 - Summary of models to estimate the protein requirements for Nellore purebred and crossbred of different genders, in feedlot

Item		Equations	Units
EBW		0.895 × SBW	kg
EBG		Nellore: 0.935 × ADG Crossbred: 0.966 × ADG	kg/day
EQEBW		Nellore: (EBW/430)× 440 Crossbred: (EBW/455)× 440	kg
NE_g		Bulls: $0.053 \times EQEBW^{0.75} \times EBG^{1.095}$ Steers: $0.064 \times EQEBW^{0.75} \times EBG^{1.095}$ Heifers: $0.072 \times EQEBW^{0.75} \times EBG^{1.095}$	Mcal/day
NP_g	Nellore	Bulls: $238.79 \times EBG - 15.68 \times NE_g$ Steers and Heifers: $163.73 \times EBG - 4.65 \times NE_g$	g/day
	Crossbred	Bulls: $219.43 \times EBG - 15.01 \times NE_g$ Steers and Heifers: $188.71 \times EBG - 7.67 \times NE_g$	g/day
k		SBW ≤ 350 kg : *k* (%) = 84.665 – 0.1179 × EQEBW SBW > 350 kg: *k* (%) = 46.9	%
MP_g		NP_g/k	g/day
MP_m		$4.0 \times BW^{0.75}$	g/day
MP_t		$MP_m + MP_g$	g/day
MCP		120 × TDN (kg/dia)	g/day
RDP		1.11 × MCP (kg/dia)	g/day
RUP		[(MP – (MCP × 0.64)]/0.80	g/day
CP		RDP + RUP	g/day

MCP= Microbial crude protein synthesis.

Table 2 - Summary of models to estimate protein requirements for Nellore cattle on pasture system

Item	Equations	Units
EBW	0.863 × SBW	kg
EBG	0.955 × ADG	kg/day
EQEBW	(EBW / 430) × 440	kg
NE_g	$0.052 \times EQEBW^{0.75} \times EBG^{1.062}$	Mcal/day
NP_g	$221.39 \times EBG - 6.61 \times NE_g$	g/day
k	SBW ≤ 350 kg : *k* (%) = 84.665 – 0.1179 × EQEBW SBW > 350 kg: *k* (%) = 46.9	%
MP_g	NP_g/k	g/day
MP_m	$4.5 \times BW^{0.75}$	g/day
MP_t	$MP_m + MP_g$	g/day
MCP	120 × TDN (kg/dia)	g/day
RDP	1.11 × MCP (kg/dia)	g/day
RUP	[(MP – (MCP × 0.64)]/0.80	g/day
CP	RDP + RUP	g/day

MCP= Microbial crude protein synthesis.

Therefore, assuming a 400 kg Nellore bull, with an ADG of 1 kg/day, in feedlot, we have:

- EBW = 0.895 × SBW = 0.895 × 400 = 358.00 kg
- EBG = 0.935 × ADG = 0.935 × 1.00 = 0.935 kg/day
- EQEBW= (EBW / 430) × 440 = (358 / 430) × 440 = 366.33 kg
- $NE_g = 0.053 \times EQEBW^{0.75} \times EBW^{1.095} = 0.053 \times 366.33^{0.75} \times 0.935^{1.095} = 4.12$ Mcal/day

- $NP_g = 238.79 \times EBG - 15.68 \times NE_g = 238.79 \times 0.935 - 15.68 \times 4.12 = 158.67$ g
- $k = 46.9$
- $MP_m = 4.0 \times BW^{0.75} = 4.0 \times 400^{0.75} = 357.77$ g
- $MP_g = (NP_g / k) = 158.67 / 0.469 = 338.32$ g
- $MP_t = MP_m + MP_g = 357.77 + 338.32 = 696.09$ g
- MCP = 120 × TDN = 120 × 5.08 kg of TDN = 609.6 g
- RDP = 1.11 × MCP = 1.11 × 609.6 = 676.66 g
- RUP = (MP – (MCP × 0.64))/0.80 = (696.09 – (609.6 × 0.64))/0.80 = 382.43 g
- CP = RDP + RUP = 1059.09 g

Table 3 - Net protein requirements for gain, expressed in g/day, for Nellore cattle of different genders, weights and rates of weight gain in feedlot

Weight gain	Body Weight					
(kg/day)	200	250	300	350	400	450
			Bulls			
0.50	93.72	90.43	87.29	84.31	81.49	78.67
0.75	139.32	134.31	129.45	124.74	120.19	115.80
1.00	184.85	177.80	171.21	164.78	158.67	152.71
1.25	230.07	221.13	212.66	204.51	196.51	188.99
1.50	275.12	264.15	253.80	243.76	234.20	224.95
			Steers			
0.50	70.16	69.00	67.88	66.81	65.79	64.77
0.75	104.73	102.92	101.15	99.48	97.90	96.31
1.00	139.32	136.81	134.44	132.16	129.93	127.79
1.25	173.82	170.61	167.59	164.66	161.83	159.08
1.50	208.23	204.32	200.60	197.07	193.63	190.28
			Heifers			
0.50	69.37	68.02	66.77	65.61	64.40	63.28
0.75	103.48	101.43	99.48	97.57	95.76	94.04
1.00	137.60	134.77	132.12	129.51	127.05	124.63
1.25	171.64	168.01	164.62	161.31	158.15	155.08
1.50	205.58	201.16	196.98	192.98	189.07	185.35

Table 4 - Net protein requirements for gain, expressed in g/day, for crossbred Zebu cattle of different genders, weights and rates of weight gain in feedlot

Weight gain	Body Weight					
(kg/day)	200	250	300	350	400	450
			Bulls			
0.50	88.87	85.72	82.72	80.02	77.17	74.61
0.75	132.37	127.57	122.91	118.41	114.21	110.00
1.00	175.34	168.74	162.44	156.28	150.43	144.87
1.25	218.39	209.83	201.73	194.07	186.57	179.36
1.50	260.92	250.56	240.65	231.20	222.19	213.33
			Steers			
0.50	80.56	78.64	76.80	75.12	73.35	71.74
0.75	120.32	117.33	114.50	111.73	109.13	106.52
1.00	159.74	155.60	151.69	148.01	144.33	140.88
1.25	199.12	193.91	188.92	184.09	179.49	175.04
1.50	238.31	231.87	225.81	219.90	214.31	208.86
			Heifers			
0.50	79.26	77.11	75.04	73.05	71.20	69.29
0.75	118.25	114.88	111.73	108.59	105.67	102.76
1.00	156.91	152.30	147.93	143.71	139.65	135.66
1.25	195.52	189.61	184.01	178.64	173.43	168.44
1.50	233.86	226.65	219.83	213.23	206.94	200.81

Table 5 - Total metabolizable protein (MP_t) requirements (maintenance + gain), expressed in g/day, for Nellore cattle of different genders, weights and rates of weight gain in feedlot

Weight gain	Body Weight					
(kg/day)	200	250	300	350	400	450
			Bulls			
0.50	361.33	408.30	455.34	503.56	53152	558.55
0.75	433.63	484.38	536.00	589.82	614.04	637.72
1.00	505.82	559.80	615.89	675.25	696.09	716.42
1.25	577.52	634.93	695.19	760.01	776.77	793.77
1.50	648.94	709.53	773.90	843.76	857.13	870.45
			Steers			
0.50	323.97	371.14	418.20	466.22	498.05	528.91
0.75	378.78	429.95	481.85	535.93	566.51	596.16
1.00	433.63	488.72	545.54	605.65	634.81	663.28
1.25	488.33	547.33	608.96	674.99	702.82	730.00
1.50	542.89	605.78	672.12	744.14	770.63	796.52
			Heifers			
0.50	322.72	369.44	416.08	463.66	495.08	525.74
0.75	376.80	427.37	478.66	531.85	561.95	591.32
1.00	430.90	485.18	541.10	600.00	628.67	656.55
1.25	484.87	542.82	603.28	667.84	694.98	721.47
1.50	538.69	600.30	665.19	735.41	760.90	786.01

Table 6 - Total metabolizable protein (MP_t) requirements (maintenance + gain), expressed in g/day, for crossbred Zebu cattle of different genders, weights and rates of weight gain in feedlot

Weight gain	Body Weight					
(kg/day)	200	250	300	350	400	450
			Bulls			
0.50	351.03	396.41	441.38	487.15	522.31	549.89
0.75	418.72	467.16	515.74	565.58	601.29	625.35
1.00	485.59	536.76	588.88	642.94	678.52	699.70
1.25	552.58	606.23	661.57	720.15	755.57	773.24
1.50	618.77	675.09	733.58	796.00	831.52	845.67
			Steers			
0.50	338.10	384.44	430.43	477.14	514.17	543.77
0.75	399.97	449.85	500.18	551.93	590.46	617.93
1.00	461.31	514.55	568.99	626.05	665.51	691.19
1.25	522.60	579.32	637.87	699.76	740.48	764.03
1.50	583.58	643.49	706.12	772.91	814.72	836.14
			Heifers			
0.50	336.07	381.85	427.17	472.91	509.58	538.55
0.75	396.75	445.71	495.06	545.52	583.08	609.91
1.00	456.91	508.97	562.03	617.27	655.53	680.06
1.25	516.99	572.05	628.78	688.62	727.56	749.96
1.50	576.66	634.67	695.06	759.29	799.01	818.98

Table 7 - Rumen degradable protein (RDP) requirements, expressed in g/day, for Nellore cattle of different genders, weights and rates of weight gain in feedlot

Weight gain	Body Weight					
(kg/day)	200	250	300	350	400	450
			Bulls			
0.50	339.66	390.28	435.56	479.52	522.14	560.77
0.75	396.94	447.55	502.16	547.45	599.40	648.68
1.00	450.22	516.82	572.76	626.04	676.66	729.94
1.25	514.15	575.42	639.36	708.62	759.24	816.52
1.50	576.76	646.02	716.62	776.56	847.15	911.09
			Steers			
0.50	350.32	402.26	452.88	495.50	542.12	587.41
0.75	414.25	472.86	524.81	583.42	631.37	683.32
1.00	479.52	547.45	610.06	667.33	725.94	781.88
1.25	548.78	618.05	684.65	756.58	827.17	891.11
1.50	622.04	695.30	772.56	853.81	916.42	983.02
			Heifers			
0.50	359.64	412.92	460.87	511.49	558.11	604.73
0.75	430.24	484.85	550.12	604.73	662.00	709.96
1.00	503.50	570.10	635.36	700.63	756.58	816.52
1.25	572.76	656.68	727.27	793.87	865.80	933.73
1.50	652.68	743.26	824.51	897.77	975.02	1049.62

Table 8 - Rumen degradable protein (RDP) requirements, expressed in g/day, for crossbred Zebu cattle of different genders, weights and rates of weight gain in feedlot

Weight gain	Body Weight					
(kg/day)	200	250	300	350	400	450
			Bulls			
0.50	342.32	392.94	438.23	483.52	531.47	575.42
0.75	404.93	459.54	515.48	562.10	607.39	658.01
1.00	466.20	522.14	583.42	632.70	692.64	747.25
1.25	530.14	592.74	659.34	717.95	779.22	828.50
1.50	586.08	667.33	736.60	801.86	860.47	921.74
			Steers			
0.50	356.98	404.93	456.88	507.49	547.45	592.74
0.75	420.91	480.85	538.13	591.41	647.35	693.97
1.00	490.18	555.44	616.72	681.98	737.93	795.20
1.25	563.44	635.36	703.30	767.23	837.83	901.76
1.50	626.04	716.62	795.20	861.80	939.06	1010.99
			Heifers			
0.50	362.30	419.58	472.86	515.48	566.10	612.72
0.75	440.89	498.17	556.78	619.38	664.67	719.28
1.00	510.16	582.08	650.02	709.96	776.56	833.83
1.25	590.08	660.67	735.26	813.85	888.44	957.71
1.50	668.66	752.58	831.17	919.08	987.01	1062.94

Table 9 - Rumen undegradable protein (RUP) requirements, expressed in g/day, for Nellore cattle of different genders, weights and rates of weight gain in feedlot

Weight gain (kg/day)	Body Weight					
	200	250	300	350	400	450
			Bulls			
0.50	206.86	229.10	255.26	283.85	288.08	294.03
0.75	255.96	282.92	308.08	342.72	335.55	329.63
1.00	307.80	327.27	357.06	392.86	382.43	369.45
1.25	351.34	378.94	408.19	439.29	423.76	403.73
1.50	395.50	421.31	450.90	495.02	460.85	431.42
			Steers			
0.50	152.48	174.01	196.35	225.66	231.84	237.78
0.75	174.92	196.64	224.07	249.43	253.10	252.72
1.00	196.44	216.34	242.25	276.10	270.31	265.58
1.25	214.89	238.72	267.76	298.46	282.37	270.26
1.50	230.29	256.11	283.35	314.82	302.81	287.17
			Heifers			
0.50	144.20	164.20	187.94	210.94	216.61	221.34
0.75	160.92	184.77	201.85	228.97	225.32	227.47
1.00	175.75	195.60	218.46	245.04	240.56	232.21
1.25	193.29	205.25	229.94	262.64	244.73	228.88
1.50	202.96	214.70	237.25	272.22	248.41	226.03

Table 10 - Rumen undegradable protein (RUP) requirements, expressed in g/day, for crossbred Zebu cattle of different genders, weights and rates of weight gain in feedlot

Weight gain (kg/day)	Body Weight					
	200	250	300	350	400	450
			Bulls			
0.50	192.07	212.31	235.89	260.46	269.85	272.64
0.75	231.56	252.75	273.16	301.86	313.85	307.45
1.00	270.99	294.63	315.62	347.68	348.95	336.07
1.25	308.65	330.59	351.76	382.75	382.86	369.43
1.50	351.06	362.90	386.10	417.08	419.24	392.77
			Steers			
0.50	165.35	188.71	208.76	230.67	248.15	252.51
0.75	196.60	215.75	237.39	263.67	271.52	272.25
1.00	223.36	242.87	266.76	291.04	300.05	290.87
1.25	247.17	266.23	290.46	321.74	321.76	305.12
1.50	278.28	287.88	309.53	345.02	341.60	316.54
			Heifers			
0.50	158.97	174.91	193.16	219.62	228.98	231.59
0.75	178.18	198.10	217.55	235.50	249.81	243.99
1.00	203.46	216.69	234.06	259.91	259.73	249.12
1.25	220.96	238.90	256.06	274.22	269.13	247.21
1.50	238.91	250.94	269.79	286.71	287.40	257.65

Table 11 - Crude protein (CP) requirements, expressed in g/day, for Nellore cattle of different genders, weights and rates of weight gain in feedlot

Weight gain (kg/day)	Body Weight					
	200	250	300	350	400	450
			Bulls			
0.50	546.52	619.38	690.82	763.37	810.22	854.80
0.75	652.90	730.47	810.24	890.17	934.95	978.31
1.00	758.02	844.09	929.82	1018.90	1059.09	1099.39
1.25	865.49	954.36	1047.55	1147.91	1183.00	1220.25
1.50	972.26	1067.33	1167.52	1271.58	1308.00	1342.51
			Steers			
0.50	502.80	576.27	649.23	721.16	773.96	825.19
0.75	589.17	669.50	748.88	832.85	884.47	936.04
1.00	675.96	763.79	852.31	943.43	996.25	1047.46
1.25	763.67	856.77	952.41	1055.04	1109.54	1161.37
1.50	852.33	951.41	1055.91	1168.63	1219.23	1270.19
			Heifers			
0.50	503.84	577.12	648.81	722.43	774.72	826.07
0.75	591.16	669.62	751.97	833.70	887.32	937.43
1.00	679.25	765.70	853.82	945.67	997.14	1048.73
1.25	766.05	861.93	957.21	1056.51	1110.53	1162.61
1.50	855.64	957.96	1061.76	1169.99	1223.43	1275.65

Table 12 - Crude protein (CP) requirements, expressed in g/day, for crossbred Zebu cattle of different genders, weights and rates of weight gain in feedlot

Weight gain (kg/day)	Body Weight					
	200	250	300	350	400	450
			Bulls			
0.50	534.39	605.25	674.12	743.98	801.32	848.06
0.75	636.49	712.29	788.64	863.96	921.24	965.46
1.00	737.19	816.77	899.04	980.38	1041.59	1083.32
1.25	838.79	923.33	1011.10	1100.70	1162.08	1197.93
1.50	937.14	1030.23	1122.70	1218.94	1279.71	1314.51
			Steers			
0.50	522.33	593.64	665.64	738.16	795.60	845.25
0.75	617.51	696.60	775.52	855.08	918.87	966.22
1.00	713.54	798.31	883.48	973.02	1037.98	1086.07
1.25	810.61	901.59	993.76	1088.97	1159.59	1206.88
1.50	904.32	1004.50	1104.73	1206.82	1280.66	1327.53
			Heifers			
0.50	521.27	594.49	666.02	735.10	795.08	844.31
0.75	619.07	696.27	774.33	854.88	914.48	963.27
1.00	713.62	798.77	884.08	969.87	1036.29	1082.95
1.25	811.04	899.57	991.32	1088.07	1157.57	1204.92
1.50	907.57	1003.52	1100.96	1205.79	1274.41	1320.59

Table 13 - Protein, requirements, expressed in g/day, for Nellore cattle of different rates of weight gain on pasture

Weight gain (kg/day)	Body Weight					
	200	250	300	350	400	450
			NP_g			
0.50	98.12	96.73	95.42	94.16	92.94	91.76
0.75	146.89	144.76	142.74	140.79	138.92	137.11
1.00	195.57	192.68	189.93	187.30	184.76	182.30
1.25	244.19	240.52	237.04	233.70	230.48	227.36
1.50	292.75	288.31	284.08	280.03	276.12	272.33
			MP_t			
0.50	393.01	447.90	502.96	564.90	600.66	635.32
0.75	469.40	529.80	591.52	664.34	698.70	732.01
1.00	545.66	611.52	679.86	763.50	796.43	828.35
1.25	621.81	693.12	768.02	862.44	893.93	924.44
1.50	697.87	774.61	856.06	961.21	991.23	1020.33
			RDP			
0.50	348.98	399.60	447.55	494.17	538.13	580.75
0.75	404.93	460.87	512.82	563.44	612.72	660.67
1.00	462.20	523.48	580.75	636.70	689.98	741.92
1.25	520.81	586.08	650.02	709.96	768.56	824.51
1.50	580.75	651.35	719.28	784.55	848.48	909.76
			RUP			
0.50	239.75	271.87	306.14	349.96	362.98	375.59
0.75	294.91	330.09	369.80	424.34	431.78	438.85
1.00	348.95	387.13	431.26	495.49	498.26	500.72
1.25	401.90	444.00	491.55	566.37	563.49	561.32
1.50	453.78	498.82	551.67	636.07	627.52	619.73
			CP			
0.50	588.73	671.47	753.70	844.13	901.11	956.34
0.75	699.84	790.96	882.62	987.78	1044.50	1099.52
1.00	811.15	910.60	1012.01	1132.19	1188.24	1242.65
1.25	922.71	1030.08	1141.57	1276.33	1332.05	1385.82
1.50	1034.54	1150.16	1270.95	1420.62	1476.00	1529.48

NP_g= net protein requirements; MP_t = Total metabolizable protein requirements.

REFERENCES

AFRC. **Energy and Protein Requirements of Ruminants**. Wallingford, UK:Agricultural and Food Research Council. CAB International, 1993. 159p.

AINSLIE, S. J.; FOX, D. G.; PERRY, T. C., et al. Predicting amino acid adequacy of diets fed to Holstein steers. **Journal of Animal Science**, v.71, p.1312-1319, 1993.

BACH, A.; CALSAMIGLIA, S.; STERN, M. D. Nitrogen metabolism in the rumen. **Journal of Dairy Science**, v.88, n.1, p.E9-E21, 2005.

BERG, R. T.; BUTTERFIELD, R. M. **New Concepts of Cattle Growth**. Sidney:Macarthur Press, 1976. 255p.

CAVALCANTE, M. A. B.; PEREIRA, O. G.; VALADARES FILHO, S. C., et al. 2005. **Níveis de proteína bruta em dietas para bovinos de corte: consumo, digestibilidade total e desempenho produtivo**, v.34, n.3, p.711-719, 2005.

CSIRO. **Nutrient Requirements of Domesticated Ruminants**. Collingwood, VIC:Commonwealth Scientific and Industrial Research Organization, 2007. 270p.

ELROD, C. C.; BUTLER, W. R. Reduction of fertility and alteration of uterine pH in heifers fed excess ruminally degradable protein. **Journal of Animal Science**, v.71, n.3, p.694-701, 1993.

EZEQUIEL, J. M. B., **Exigências de proteína e minerais de bovídeos: frações endógenas**. 1987. 131p.Tese (Doutorado em Zootecnia) - Universidade Federal de Viçosa, Viçosa, MG, 1987.

FOX, D. G.; BLACK, J. R. A system for predicting body composition and performance of growing cattle. **Journal of Animal Science**, v.58, n.3, p.725-739, 1984.

GEAY, Y. Energy and protein utilization in growing cattle. **Journal of Animal Science**, v.58, n.3, p.766-778, 1984.

GIONBELLI, M. P., **Desempenho produtivo e exigências nutricionais de fêmeas Nelore em crescimento**. 2010. 106p. Dissertação (Mestrado em Zootecnia) - Universidade Federal de Viçosa, Viçosa, MG, 2010 (no prelo).

INRA - INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE-. **Alimentation des bovines, ovins, et caprins**. Paris, FR:INRA, 1988. 192p.

KLEMESRUD, M. J.; KLOPFENSTEIN, T. J.; STOCK, R. A., et al. Effect of dietary concentration of metabolizable lysine on finishing cattle performance. **Journal of Animal Science**, v.78, n.4, p.1060-1066, 2000.

MAGALHÃES, K. A.; VALADARES FILHO, S. C.; VALADARES, R. F. D., et al. Produção de Proteína Microbiana, Concentração Plasmática de Uréia e Excreções de Uréia em Novilhos Alimentados com Diferentes Níveis de Uréia ou Casca de Algodão. **Revista Brasileira de Zootecnia**, v.34, n.4, p.1400-1407, 2005.

MARCONDES, M. I.; VALADARES FILHO, S. C.; OLIVEIRA, I. M., et al. Requerimentos de proteína de animais Nelore puros e cruzados com as raças Angus e Simental. **Revista Brasileira de Zootecnia**, 2010 (submetido).

MARCONDES, M. I.; VALADARES FILHO, S. C.; PAULINO, P. V. R., et al. Exigências nutricionais de proteína, energia e macrominerais de bovinos Nelore de três classes sexuais. **Revista Brasileira de Zootecnia**, v.38, n.8, p.1587-1596, 2009.

NRC. **Nutrient Requirements of Beef Cattle**. 6th.ed. Washington, DC:National Academy Press, 1984. p.

NRC. **Nutrient Requirements of Beef Cattle**. 7th.ed. Washington, DC:National Academy Press, 1996. 242p.

NRC. **Nutrient Requirements of Beef Cattle**. updated 7th.ed. Washington, DC:National Academy Press, 2000. 242p.

NRC. **Ruminant Nitrogen Usage**. Washington, DC:National Academy Press, 1985. 138p.

OLDHAM, J. D. Efficiencies of amino acid utilization. In: JARRIGE, R.; ALDERMAN, G.(Ed). **Feed Evaluation and Protein Requirement Systems for Ruminants**.ed. Brussels: Commission of the European Communities, 1987. 171-186

SMUTS, D. The relation between the basal metabolism and the endogenous nitrogen metabolism, with particular reference to the maintenance requirement of protein. **Journal of Nutrition**, v.9, n.4, p.403-433, 1935.

SUSMEL, P.; SPANGHERO, M.; STEFANON, B., et al. N losses, purine N derivates excretion and intestinal digestible protein requirements of cows for maintenance. **Livestock Production Science**, v.36, n.3, p.213-222, 1993.

TODD, R. W.; COLE, N. A.; CLARK, R. N. Reducing crude protein in beef cattle diet reduces ammonia emissions from artificial feedyard surfaces. **Journal of Environmental Quality**, v.35, n.2, p.404-111, 2006.

VALADARES, R. F. D.; GONÇALVEZ, L. C.; SAMPAIO, I. B., et al. Protein levels in cattle diets. 2. Intake, digestibilities, and nitrogen balance. **Revista Brasileira de Zootecnia**, v.26, n.6, p.1259-1263, 1997.

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, MG:Suprema Grafica Ltda, 2006. 142p.

VANDERWERT, W.; BERGER, L. L.; MCKEITH, F. K., et al. Influence of zeranol implants on growth, behaviour and carcass traits in Angus and Limousin bulls and steers. **Journal of Animal Science**, v.61, n.2, p.310-319, 1985.

VÉRAS, R. M. L., **Consumo, digestibilidades total e parcial, produção microbiana e exigências de proteína para mantença de bovinos Nelore**. 2006. 115p.Tese (Doutorado em Zootecnia) - Universidade Federal de Viçosa, Viçosa, MG, 2006.

WILKERSON, V. A.; KLOPFENSTEIN, T. J.; BRITTON, R. A., et al. Metabolizable protein and amino acid requirements of growing cattle. **Journal of Animal Science**, v.71, n.10, p.2777-2784, 1993.

ZINN, R. A.; OWENS, F. N. Influence of feed intake level on site of digestion in steers fed a high concentrate diet. **Journal of Animal Science**, v.56, n.2, p.471-475, 1983.