ENERGY REQUIREMENTS OF ZEBU BEEF CATTLE

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INTRODUCTION

Projections for beef cattle production in Brazil for the next 10 years forecast an annual increase of about 3.5%. For the same period, a 2.22% growth in the domestic intake of beef cattle and an increase of 3.07% a year in exportation is estimated. This annual increase in exportation could reach 3.4 million tons by 2019, establishing Brazil as the main beef exporting country (MAPA/AGE, 2009). This increase in exports should happen together with improvements in national beef quality and with changes that meet international demands, such as increased tenderness, lower age at slaughter and a better finishing standard, all of which will add value to national beef. With the increase in production and export will come an increase in the cattle finished in feedlot and in the use of industrial crossbreeding. Grain production and poultry, swine and milk production will also show pronounced annual increase rates, improving competitiveness in agribusiness and eliminating those producers that are less effective.

Rising concern from environmentalists could limit the progress of livestock farming in new areas, thus making improvements in productivity in existing areas essential for increased production. Therefore, appropriate technologies should be developed and set in place to enable the expansion of beef cattle production.

As feeding corresponds to the largest part of operating costs and is one of the main factors affecting animal performance, the search for and the adoption of more rational feed management have the potential to greatly impact both quality and economics in beef cattle production systems. The technologies being adopted in our territory in the field of livestock agriculture should be developed in Brazil, where the cattle herd composition, available feed and climate are typical of a tropical environment.

Beef cattle production systems in Brazil are based on pasture covered with tropical grass. The cattle are predominantly zebuine, and the Nellore breed is the most common. More than 80% of the Brazilian herd shows some genetic composition coming from this Zebu breed (Ripamonte, 2002). According to Sainz et al. (2006), the Nellore, with more than 100 million heads spread around the country, has become the main breed due to its adaptability to tropical environments conditions, such as: hot and moist weather; the presence of endo- and ectoparasites; and the irregular pattern, qualitative or quantitative, of avaliable feed,

Therefore, determining the nutritional requirements of our herd means offering Brazilian society a production technology created under our conditions, which are markedly distinct from those present in countries of temperate climates. The balance of rations and supplements for determined levels of performance, as well as performance estimated from balanced diets, requires the knowledge of nutritional requirements for different functions and for different levels of performance (Boin, 1995).

NUTRITIONAL REQUIREMENTS

For more than a century, global scientific research about animal nutrition has defined the nutrients required by animals (Preston, 2006). Knowing the the concentration or amount of each nutrient in the diet that a specific animal demands to obtain optimal performance, together with knowledge of the nutritional value of the available feeds, are the basis of the diet formulation. These factors are also important for planning and implementing nutritional management in an efficient, technical and economical way.

Several countries have already established nutritional patterns for their cattle, taking into account their unique conditions: France in 1978 (INRA, 1978 and INRA, 2007); England in 1965 (ARC, 1965); the United Kingdom in 1980 (ARC, 1980) and 1993 (AFRC, 1993); the United States (NRC, 1917 to NRC, 2000); and Australia in 1990 (CSIRO, 1990 and CSIRO, 2007). In Brazil, the first version of nutrient requirements of zebu beef cattle (BR CORTE), (Valadares Filho et al., 2006) showed the requirements of Nellore cattle raised under Brazilian conditions. However, a reduced number of observations (mainly for steers and heifers cattle) and the lack of crossbred animals in the database suggests that an update in the nutritional requirements of beef cattle in Brazil should be performed.

ENERGY REQUIREMENTS

Energy is defined as the potential to do work, and exists in several forms. Energy can only be measured during its change from one form to another. In nutrition, the energy contained in feeds, feces, urine and tissues is measured through the complete combustion of the sample in a calorimeter. This calorimeter causes an increase in the temperature of the water surrounding the combustion chamber, which is quantified and converted into caloric units. One calorie (cal) is the amount of energy necessary to raise the temperature of 1 g of water 1ºC (14.5 to 15.5ºC). Although the calorie is more traditional, it is not considered the standard unit by the International Metric System, which uses the Joule (1 cal is equivalent to 4.1840 J). The reason for the adoption of Joule is its inter-convertibility into other energy units used by other branches of science. Many European systems have already adopted the J as the standard unit. However, for the United States and Latin America, the cal remains the usual unit. Considering that the majority of Brazilian nutritionists are familiar with cal, this unit will be adopted in the current edition.

The energy used by animals is obtained from feeds through digestive and metabolic processes. These processes are considered energetically inefficient, due to the energy loss that occurs at each of the several nutrient assimilation stages.

This energy is represented by the following: gross energy (GE); digestible energy (DE); metabolizable energy (ME); and net energy (NE).

Gross energy represents the total energy (heat) released during the complete oxidation of a sample in a calorimeter, but it has limited use in animal nutrition because it does not indicate the availability of this energy for the animal. The apparent digestible energy is the difference between the GE intake and the energy excreted through feces, and it is usually determined in digestibility trials. Metabolizable energy is calculated by subtracting from the DE the energy losses through urine and gases, and represents the energy fraction to be used by the animal or lost as heat. The proportion of energy lost in the form of urine and gases in balanced diets varies little, thus ME has been calculated as 82 % of DE. The net energy is defined as the amount of available energy for maintenance and productive processes, and it is subdivided, according to the differences in energy efficiency, into net energy for maintenance and net energy for production.

DATABASE

To update the nutrient requirements of zebu beef cattle (BR-CORTE), a database was built with 25 studies developed under Brazilian conditions. These studies are as follows: Galvão et al. (1991); Boin (1995, three studies); Jorge et al. (1997);

Ferreira et al. (1998); Paulino et al. (1999); Véras et al. (2001); Silva et al. (2002); Veloso et al. (2002); Martins (2003); Paulino et al. (2004); Backes et al. (2005); Leonel et al. (2006); Putrino et al. (2006); Chizzotti et al. (2007); Paixão (2008); Machado (2009); Marcondes et al. (2009); Paulino et al. (2009); Porto (2009); Sales et al. (2009); Gionbelli (2010); Marcondes et al. (2010a); and Souza et al. (2010). A summary of the database is shown on Tables 1 to 3.

Among the presented data, 626 animals were studied in feedlot and another 127 under pasture conditions. The number of Nellore x European crossbreeds in each group were as follows: 7 Nellore x Holstein, 62 Nellore x Simental, 57 Nellorex Limousin and 12 Nellore x Marchigiana; 75 F_1 Nellore x Angus; 23 Brangus and 8 bi-crossbred animals, with a higher fraction of European crossbreed coming from the Angus.

Table 1 - Descriptive statistics of Brazilian data of feedlot cattle used to obtain the energy requirements of Nellore cattle

Items	N	Average	Maximum	Minimum	DP
			Bulls		
SBWi, kg	179	291.25	437.70	151.05	61.97
SBWf, kg	183	401.18	532.53	210.01	69.43
EBWi, kg	179	251.24	357.62	130.41	52.13
EBWf, kg	190	353.40	466.40	177.51	63.80
EBW_M, $kg^{0.75}$	183	72.53	90.33	47.81	9.40
ADG, kg/day	178	0.91	1.72	0.09	0.38
EBG, kg/day	178	0.93	1.79	-0.04	0.38
RE, Kcal/$EBW^{0.75}$	183	43.69	170.16	-102.15	37.35
MEI, Kcal/$EBW^{0.75}$	183	227.28	467.49	81.75	62.27
HP, Kcal/$EBW^{0.75}$	183	183.59	391.57	20.60	54.52
			Steers		
SBWi, kg	110	301.26	399.00	197.00	39.92
SBWf, kg	114	383.34	519.50	233.50	58.78
EBWi, kg	110	265.49	352.01	156.15	36.83
EBWf, kg	124	337.33	469.47	200.53	60.52
EBW_M, $kg^{0.75}$	110	73.23	89.59	51.90	7.21
ADG, kg/day	110	0.71	1.41	-0.18	0.40
EBG, kg/day	110	0.70	1.32	-0.21	0.37
RE, Kcal/$EBW^{0.75}$	110	52.70	103.13	0.64	26.33
MEI, Kcal/$EBW^{0.75}$	110	215.01	309.53	114.10	52.03
HP, Kcal/$EBW^{0.75}$	110	162.31	231.89	104.47	30.49
			Heifers		
SBWi, kg	53	231.37	341.50	133.50	56.96
SBWf, kg	61	288.39	436.50	126.50	75.71
EBWi, kg	53	205.67	297.02	112.93	53.89
EBWf, kg	68	259.59	397.49	107.74	69.34
EBW_M, $kg^{0.75}$	53	60.74	80.15	36.96	10.99
ADG, kg/day	53	0.67	1.27	-0.12	0.42
EBG, kg/day	53	0.66	1.25	-0.13	0.38
RE, Kcal/$EBW^{0.75}$	53	58.45	131.65	-3.61	34.39
MEI, Kcal/$EBW^{0.75}$	53	223.44	325.68	111.57	66.59
HP, Kcal/$EBW^{0.75}$	53	164.98	232.90	-92.55	50.87

SBWi = initial shrunk body weight; SBWf = final shrunk body weight; EBWi = initial empty body weight; EBWf = final empty body weight; EBW_m = mean metabolic empty body weight; ADG = average daily weight gain; EBG = empty body weight gain; RE = retained energy; MEI = metabolizable energy intake; HP = heat production.

Table 2 - Descriptive statistics of Brazilian data of feedlot cattle used to obtain the energy requirements of crossbred Nellore x *Bos taurus*

Items	N	Average	Maximum	Minimum	DP
			Bulls		
SBWi, kg	140	318.39	466.80	198.00	51.96
SBWf, kg	140	471.01	585.10	248.00	67.88
EBWi, kg	140	267.86	370.99	172.59	41.41
EBWf, kg	143	410.27	499.38	218.03	67.68
EBW_M, $kg^{0.75}$	140	79.19	93.61	56.00	8.57
ADG, kg/day	140	1.12	1.93	-0.08	0.37
EBG, kg/day	140	1.08	2.04	-0.05	0.38
RE, Kcal/$EBW^{0.75}$	140	49.09	111.71	-6.72	20.00
MEI, Kcal/$EBW^{0.75}$	140	232.72	342.31	109.63	52.86
HP, Kcal/$EBW^{0.75}$	140	183.63	288.72	84.19	44.75
			Steers		
SBWi, kg	41	355.37	433.50	260.00	41.44
SBWf, kg	49	428.51	552.00	264.50	80.30
EBWi, kg	41	311.57	384.91	204.60	48.77
EBWf, kg	52	381.72	506.08	201.06	83.14
EBW_M, $kg^{0.75}$	41	82.49	94.76	58.48	9.33
ADG, kg/day	41	0.93	1.72	-0.36	0.62
EBG, kg/day	41	0.99	1.64	-0.09	0.58
RE, Kcal/$EBW^{0.75}$	41	63.93	108.29	9.49	30.62
MEI, Kcal/$EBW^{0.75}$	41	226.91	314.66	119.55	65.65
HP, Kcal/$EBW^{0.75}$	41	162.98	225.99	100.80	37.81
			Heifers		
SBWi, kg	38	270.96	331.00	194.00	33.49
SBWf, kg	46	345.22	494.00	186.50	88.50
EBWi, kg	38	241.08	311.19	149.56	36.79
EBWf, kg	49	304.22	442.71	175.47	79.76
EBW_M, $kg^{0.75}$	38	69.01	83.20	46.89	9.14
ADG, kg/day	38	0.86	1.75	-0.31	0.66
EBG, kg/day	38	0.80	1.73	-0.18	0.58
RE, Kcal/$EBW^{0.75}$	38	55.16	104.39	-7.60	33.37
MEI, Kcal/$EBW^{0.75}$	38	237.50	354.70	111.55	82.78
HP, Kcal/$EBW^{0.75}$	38	182.34	267.87	102.76	53.28

SBWi = initial shrunk body weight; SBWf = final shrunk body weight; EBWi = initial empty body weight; EBWf = final empty body weight; EBW_m = mean metabolic empty body weight; ADG = average daily weight gain; EBG = empty body weight gain; RE = retained energy; MEI = metabolizable energy intake; HP = heat production.

Table 3 - Descriptive statistics of Brazilian pasture finished Nellore used to obtain the energetic requirements of Zebu cattle

Items	N	Average	Maximum	Minimum	DP
			Bulls		
SBWi, kg	82	302.21	404.00	137.50	50.59
SBWf, kg	92	329.30	489.50	137.50	68.64
EBWi, kg	79	274.14	363.30	176.27	41.40
EBWf, kg	99	290.53	438.15	118.48	58.85
EBW_M, $kg^{0.75}$	82	69.16	89.28	35.91	9.28
ADG, kg/day	79	0.42	1.13	-0.54	0.38
EBG, kg/day	79	0.34	0.81	-0.55	0.36
RE, Kcal/$EBW^{0.75}$	79	24.27	105.02	-52.29	29.13
MEI, Kcal/$EBW^{0.75}$	79	198.76	306.74	83.39	54.47
HP, Kcal/$EBW^{0.75}$	79	174.49	339.45	12.71	59.66
			Steers		
SBWi, kg	20	316.78	409.00	226.00	59.75
SBWf, kg	28	322.82	484.00	150.00	91.67
EBWi, kg	20	261.17	337.21	186.33	49.26
EBWf, kg	28	266.58	405.49	124.45	76.95
EBW_M, $kg^{0.75}$	20	68.29	84.59	51.81	9.66
ADG, kg/day	20	0.57	0.95	-0.15	0.33
EBG, kg/day	20	0.47	0.90	-0.10	0.29
RE, Kcal/$EBW^{0.75}$	20	16.28	36.92	-12.37	15.46
MEI, Kcal/$EBW^{0.75}$	20	209.55	306.19	119.98	54.72
HP, Kcal/$EBW^{0.75}$	20	193.27	277.87	128.64	41.29

SBWi = initial shrunk body weight; SBWf = final shrunk body weight; EBWi = initial empty body weight; EBWf = final empty body weight; EBW_m = mean metabolic empty body weight; ADG = average daily weight gain; EBG = empty body weight gain; RE = retained energy; MEI = metabolizable energy intake; HP = heat production.

EMPTY BODY WEIGHT AND EMPTY BODY WEIGHT GAIN

The first step to determine the nutritional requirements of animals is the conversion of shrunk body weight (SBW) into empty body weight (EBW). There were no effect of breed or gender group ($P > 0.05$) over the relationship of EBW and SBW. The equations presented below are related to the raising system:

Feedlot $EBW = 0.895 \times SBW$
Pasture $EBW = 0.863 \times SBW$

where EBW is the empty body weight and SBW is the shrunk body weight, both in kg.

The results show a higher empty body to shrunk body weight proportion for animals finished in feedlot than those finished in pasture. This effect could be the result of an increase in filling promoted by the pasture intake, considering that animals under feedlot usually have a greater proportion of their diet in the form of concentrate feeds. The BR-CORTE (2006) and the NRC (2000) have shown fixed values for the SBW/EBW ratios of 0.896 and 0.891, respectively. However, the NRC (2000) reported that this rate could vary from 85 to 95%. Chizzotti et al. (2008), using a meta-analysis of purebred and crossbred Zebu cattle, showed a SBW/EBW ratio according to the following equation: $EBW = -15.6 + 0.928 \times SBW$.

The average daily weight gain (ADG): empty body weight gain (EBG) ratio was affected by the genetic group ($P = 0.0003$) in the feedlot system. Thus, the EBG can be estimated from the following equations:

Feedlot	Nellore	$EBG = 0.936 \times ADG$
	Crossbred	$EBG = 0.966 \times ADG$
Pasture		$EBG = 0.955 \times ADG$

where EBG is the empty body weight gain and ADG is the average daily weight gain, both in kg/day.

It is clear that Nellore cattle have a lower EBG than the crossbred cattle. These results support the literature. BR-CORTE (2006), using only Nellore animals, has suggested a conversion value of 0.933. The NRC (2000) utilizing *Bos taurus* animals, has suggested a conversion of 0.951. However, Chizzotti et al. (2008), while evaluating purebred and crossbred zebu cattle, suggested a mean value of 0.961.

MATURITY WEIGHT

Until now, maturity weight has always been connected to the stable weight of adult cows of a determined breed. However, the application of this value for growing animals may not be satisfactory. Some breeds, such as European Continental breeds, reach a certain weight at the adult stage that is above the slaughter weight normally adopted by the national beef cattle market . Also, many of these animals are stable much earlier in their fat free composition (Reid et al., 1955), and there is an increase in their weight solely as a consequence of increased fat, which is, therefore, dependent on the diet offered to the animal.

To determine the weight of cattle at maturity, it would be helpful to have a study of the growth curves from birth to adulthood. Several researchers have connected growth with age (Brown et al., 1976; Menchaca et al., 1996). However, the evolution of nutritional knowledge has given rise to management conditions that changed the weight gain rate, consequently altering the growth curve of the animals. Therefore, the study of growth curves compared with body weight and composition has become one of the most important factors in determining more concretely (e.g., less empirically) the maturity of cattle.

Arnold and Bennett (1991a,b) studied the model proposed by Sanders and Cartwright (1979a,b), and they suggested a weight at maturity of 517 kg for bulls, 520 kg for steers and 315 kg for heifers of medium-sized breeds (Hereford-Shorthorn). The model proposed by Oltjen et al. (1986), also with medium-sized animals (Angus-Hereford), estimated a mature weight of 450 kg for steers. Because Nellore cattle are also considered to be of average size (NRC, 1996), these differences may be important, as most nutritional requirement systems (NRC, 1996; CSIRO, 2007) already consider weight at maturity in estimating properly the nutritional needs. According to Taylor et al. (1980), analyzing the *inputs* and *outputs* of variables that are likely connected to maturity may be a way of estimating maturity. Some studies have been done with *Bos taurus* animals (Berg and Butterfield, 1976); however, the evaluation of the growth of *Bos indicus* animals to determine their maturity is not yet conclusive.

Using the BR-CORTE data, excluding those animals that were kept under a maintenance system, it was possible to trace curves by comparing the content of ether extract, crude protein, water and minerals with the empty body weight of Nellore cattle and their crosses, with the aim of determining the weight that best represents the maturity of those animals.

According to Reid et al. (1955), the chemical maturity of the animals is reached when their crude protein (CP) concentration in fat-free dry matter (FFDM) becomes constant. In this way, a point was determined at which there was no significant increase ($P < 0.05$) in crude protein in the fat-free dry matter for a 10 kg variation in EBW, thus reaching the plateau of protein deposition.

For Nellore cattle, this plateau was reached with 428.5 kg of EBW, and it was represented by a concentration of 78.47% of CP in FFDM. For crossbred cattle, this plateau was obtained at 453.6 kg of EBW and 81.0 % of CP in FFDM. These results demonstrate that purebred Nellore cattle reach chemical maturity before their european crosses.

Tedeschi et al. (2002) suggested that maturity should be represented by the shrunk body weight of Nellore cattle that reached 22% of the ether extract in an empty body weight, which was represented as 365 kg weight for young bulls and steers and 456 kg for late maturity bulls. However, this recommendation does not seem to be the best suited once the ether extract content in the empty body weight is strongly affected by the diet (Coleman et al., 1993; Albin et al., 1967; Guenther et al., 1965; Henrickson et al., 1965). This representation is not, therefore, recommended as a standard value of a breed or gender. Using the data described above and considering the ether extract content of 22% in empty body as a maturity point for animals, an empty body weight at maturity of 464.6 kg would be obtained for Nellore cattle and of 516.3 for crossbred cattle.

Despite the higher weight values expected at maturity of large animals such as the Continental European breeds, the 516.3 kg value for crossbred animals seems to be above that predicted, as in Brazil it is normal to work with a slaughter weight below 500 kg. However, the high heterosis of crossbred animals promotes an increase in performance of the animals (Marcondes et al., 2010a), which could cause a higher deposition of protein tissue and, therefore, more time to establish the crude protein content in the FFDM.

The NRC (2000) suggests that a correction must be made in the weight of animals of different body sizes or weights at maturity for energy gain requirements. The average weight at maturity of all evaluated genetic groups was 440 kg. Therefore, it is possible to calculate the equivalent EBW (EQEBW) from the weight value at maturity suggested previously. This correction allows a comparison of several racial groups of animals at different finishing points. The model adopted by BR-CORTE is:

$$EQEBW = (EBW / EBW_{mat}) \times EBW_{ref}$$

where EQEBW is the equivalent empty body weight; EBW_{ref} is the reference empty body weight in all animals that would be at the same maturity point (440 kg); and EBW_{mat} is the EBW at maturity for the evaluated genetic groups (430 kg for Nellore and 455 kg for crossbred).

It is evident that the suggested values above are round-offs of those shown previously; this was done to make the nutritional requirement calculation procedure simpler.

NET ENERGY REQUIREMENTS FOR MAINTENANCE

The net energy requirements for maintenance(**NE_m**) has been calculated using the comparative slaughter method. In this method, the heat production is not directly measured but is obtained by the difference between the metabolizable energy intake and the retained energy in the empty body. To use this method, it is necessary to fed animals with different levels of metabolizable energy (by restricting the diet or using different levels of concentrate). These different levels will result in a variation of retained energy in the body and in heat production. The **NE_m** has been calculated as an antilogarithm of the intercept of the regression equation of the logarithm of heat production on the metabolizable energy intake (MEI), according to Lofgreen and Garret (1968), representing the heat production (HP) of a fasting animal. Due to the development of statistical software, the use of logarithmic data has decreased, been more appropriated the use of non-linear exponential models to describe the relationship between HP and MEI according to the model:

$$HP = \beta_0 \times e^{\beta_1 \times MEI}$$

where HP is the heat production (Mcal/EBW$^{0.75}$), MEI is the daily metabolizable energy intake (Mcal/EBW$^{0.75}$), β_0 and β_1 are regression parameters and “e” is the Euler number.

Under this model, β_0 represents the net requirements for maintenance. By the iterative method, the point where MEI equals to HP can be determined, and this point can be considered the metabolizable energy requirement for maintenance (ME_m). The efficiency of use of metabolizable energy for maintenance (k_m) is obtained from the relation between the net and metabolizable energy requirements for maintenance, i.e., $k_m = NE_m/ME_m$.

Table 4 shows the results for the first BR-CORTE version (2006), using only Nellore cattle for different gender classes. The model has used the logarithmic method for estimating the regression coefficients and that there was no effect of gender on maintenance requirements.

Table 4 - Regressions of logarithm of heat production (HP, Kcal/EBW$^{0.75}$) as a function of metabolizable energy intake (MEI, Kcal/EBW$^{0.75}$) and estimate of net (NE_m) and metabolizable (ME_m) energy requirements for maintenance, expressed in Kcal/EBW$^{0.75}$ of Nellore cattle of different gender

Gender class	Intercept	Slope	r^2	MSE	NE_m	ME_m	k_m[1]
Bulls	1.8992	0.0015	0.8515	0.035	79.28	120.0	0.66
Steers	1.8861	0.0016	0.8274	0.038	76.93	119.5	0.64
Heifers	1.8912	0.0016	0.8788	0.027	77.84	122.2	0.64
All	1.8949	0.0016	0.8512	0.035	78.50	123.9	0.63

MSE = estimate of mean standard error.
$k_m = NE_m/ME_m$.

After a study developed by Lofgreen and Garret (1968), the NRC (2000) established that the net energy requirements for maintenance of heifers and steers would be 77 kcal/EBW$^{0.75}$. Chizzotti et al. (2008) estimated maintenance requirements of 75 kcal/EBW$^{0.75}$/day in a study involving the analysis of data of 389 Nellore cattle, which were purebred or crossbred with *Bos taurus*.

Using the new database of BR-CORTE, the NE_m requirements for zebu cattle were estimated considering the effects of gender, genetic group and feeding system. Due to the unequal number of data and to the specific feeding conditions, the NEm models for feedlot and pasture raised cattle were made separately.

No differences were observed in coefficients β_0 and β_1 for gender class and genetic group of animals raised in feedlot or for those raised under grazing conditions, leading to the recommendation of two models (one for animals under feedlot and another for animals in pasture), as seen below:

Feedlot $HP = 0.0742 \times e^{3.703 \times MEI}$
Pasture $HP = 0.0717 \times e^{4.439 \times MEI}$

where HP is heat production (Mcal/EBW$^{0.75}$/day) and MEI is metabolizable energy intake (Mcal/EBW$^{0.75}$/day).

The NE_m is equivalent to the heat produced by the fasting animal, i.e., without any feed support to attend any other energetic need, measuring the animal heat production that represents the amount of energy dispensed for strictly basal activities, such as breathing, circulation, homeothermy, organs function and enzymatic systems. For several animal (groups), the measurement of fasting heat production in a respirometry chamber is unfeasible, nonetheless its deduction by mathematic models is plausible. The NE_m value is, therefore, an estimated value and is, theoretically, independent of the diet.

Although the NE_m is independent of the diet, the highest NE_m value found for feedlot animals (74.2 Kcal/$EBW^{0.75}$/day) compared with animals in pasture (71.7 Kcal/$EBW^{0.75}$/day) is a function of rearing conditions. The difference found, although not statistically tested, seems to be connected to the fact that animals that are raised on pasture develop adaptations in their basal metabolism to withstand environmental conditions, reducing the energy cost associated with basic vital functions. It is also important to consider that the two observed values are close to the basal metabolic rate measured in respirometry chamber, suggested for adult homeothermic mammals, of 69 kcal/$EBW^{0.75}$/day (Poczopko, 1971).

However, as shown in Figure 1, with feed intake (metabolizable energy intake), the heat production by animals in pasture increases in a more pronounced way compared with confined animals. This increase leads to higher estimates of metabolizable energy requirements for maintenance, as will be shown in section 3.5.

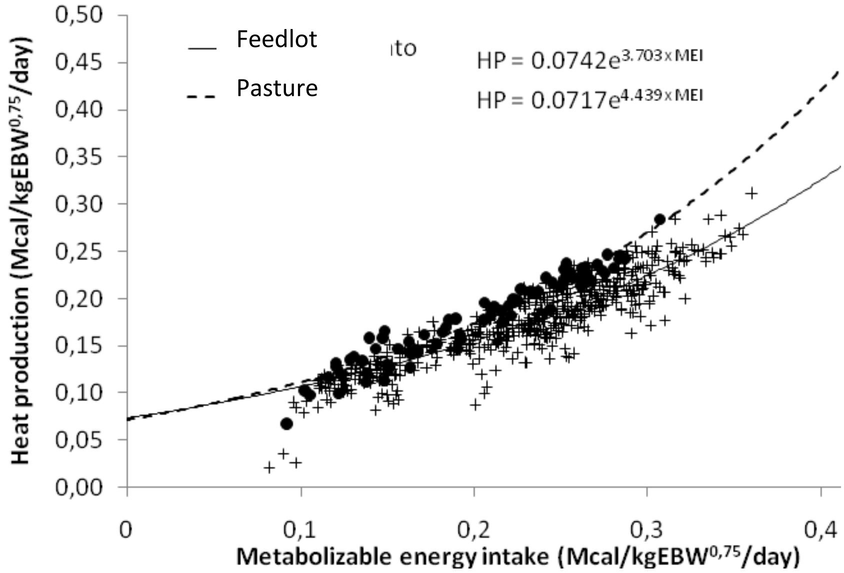

Figure 1 - Exponential relationship between heat production (HP) and metabolizable energy intake (MEI) of purebred and crossbred Zebu cattle under feedlot (+, n = 554) and pasture (●, n = 78) conditions.

Reviewing the dataset from several Zebu breeds, NRC (2000) concluded that a 10% discount should be applied, which would result in net energy requirements for maintenance of 69 kcal/$EBW^{0.75}$/day. The NRC (2000), along with the ARC (1980) and CSIRO (1990), also suggests that there are no differences between steers and heifers (Garret, 1980). However, the NRC (2000) suggests that bulls would have a NE_m requirement that is between 9 and 20% higher than the other classes (Ferrell and Jenkins, 1985; Webster et al., 1982).

Chizzotti et al. (2008), comparing purebred Nellore with Nellore crosses with taurine breeds (Angus, Red Angus, Simental, Limousin and Brangus), did not detect any difference between pure (n=271) and crossbred (n=118) cattle. It should be noted that the data for this study were of animals with taurine paternity, i.e., *Bos taurus* bulls with Nellore cows. The father's breed can have a lower influence on the heat production because it is known that at the moment of fertilization, the sperms' mitochondria, situated at the base of the tail, are not transferred to the egg. Consequently, the mitochondrial genetic information of the generated animal is similar only to the maternal mitochondria. As the mitochondria represent a significant part of the animal heat production (Harper et al., 2002), it would be expected that the mitochondrial heat production would be influenced mainly by maternal breed. Thus, the absence of breed effects on crossbred animals from these dataset likely can be attributed to the mitochondrial similarity with purebred, due to the maternal cytoplasmic inheritance (Wagner, 1972)..

METABOLIZABLE ENERGY REQUIREMENTS FOR MAINTENANCE

The definition of NE_m as the animal's fasting HP prevents its direct use in ration formulation, because animals in production are not fasting, and therefore NE_m should be converted to metabolizable energy for maintenance (**ME_m**). For this purpose, it is necessary to know the efficiency of use of the metabolizable energy for maintenance (***k_m***). Using the exponential relation between heat production and metabolizable energy intake (Figure 1), it is possible to establish the ME_m requirements adopting an iterative process. This process makes the HP equal to the MEI, i.e., when all of the MEI is lost in the form of heat (HP=MEI), there will be no energy retention, and this MEI is equivalent to the ME_m requirement. By using this procedure, the k_m will be obtained when the NE_m is divided by the ME_m.

This method was used by Valadares Filho et al. (2006) to estimate the ME_m and k_m requirements in the latest BR-CORTE edition (Table 4). The k_m reported by these authors was 0.63. Chizzotti et al. (2008) estimated a k_m of 0.67, and no breed or gender effects were detected on the estimate of this parameter.

According to CSIRO (2007), factors such as gender, breed, age and environment affect k_m. However, k_m has only been estimated from the metabolizable energy concentration of the diet (AFRC, 1993; NRC, 2000; CSIRO, 2007). By using the BR-CORTE database, Marcondes et al. (2010a) did not evidence the relationship between k_m and the ME concentration in the diet. Johnson et al. (1977) also reported problems in the use of this variable to estimate the k_m, reporting that the model is not appropriate when low digestibility feeds are used (the type of feed that is common under tropical conditions).

One of the great challenges for nutritional requirement models is determine the factors that affect the k_m and ME_m requirements, considering that HP is affected by the rate and composition of weight gain (Willians and Jenkins, 2003). Marcondes et al. (2010b) studied the effects of several variables on the k_m. The study was developed by estimating the k_m obtained in each experiment and correlating the k_m values with several variables. The partial efficiency of the use of metabolizable energy for gain (***k_g***) and the empty body weight gain (EBG) affected the k_m, which suggests that the maintenance requirements are affected by the performance of the animals. The genetic group significantly affected the regression parameters. Therefore, the genetic group was divided into purebred Nellore and crossbred cattle due to the low number of repetitions (n = 25) to make a deeper analysis of breed effects. However, gender did not affect the k_m. The final model suggested by the authors was:

$k_m = 0.513 + 0.173 \times k_g + a \times EBG$

where *a* is equal to 0.100 for Nellore cattle and 0.073 for crossbred (*Bos taurus* x *Bos indicus*).

Despite the absence of genetic group effects on NE_m, the equation above may introduce a new concept of how this factor influences maintenance requirements. The NRC (2000) suggests that *Bos indicus* would have 10% less NE_m. However, the k_m equation indicates that this difference may not be related to the net maintenance requirement, but to the efficiency of NE_m use. *Bos indicus* cattle would be more efficient in converting the metabolizable energy into net energy for maintenance when compared with *Bos Taurus* or, in this case, *Bos indicus* × *Bos taurus*.

Garrett (1980) suggested that the body composition and nutrition plan affect the k_m. The suggested model supports this idea, where the k_g is affected by the gain composition (as shown ahead), and the EBG is also an effect of the nutrition plan. Furthermore, the author explains that the protein *turnover* can be responsible for part of the k_m variation; thus, the evaluated breeds would have differences in their protein *turnover*.

Although no studies supporting the above hypothesis are found in the literature, Lobley et al. (2000) showed that animals with a lower protein *turnover* have less tender meat. Several studies show that *Bos indicus* have less tender meat when compared with *Bos taurus* (Whipple et al., 1990; Shakelford et al., 1991; Restle et al., 1999). Therefore, this lower energetic expenditure with protein *turnover*, indicated by a lower tenderness of the meat of *Bos indicus*, may provide a higher efficiency in the use of metabolizable energy for these animals.

Due to the use of studies as experimental units, Marcondes et al. (2010b) did not make comparisons among feedlot and pasture conditions for the development of k_m models. However, the models generated for the HP connected to the MEI of confined and grazing animals, shown in the previous section, make possible to state that there are differences in the efficiency of the use of metabolizable energy for maintenance between the two feeding systems (Figure 1).

When calculating the ME_m value for confined animals by the iterative method using the model shown in Figure 1 ($HP = 0.0742 \times e^{3.703 \times MEI}$), a ME_m of 112.4 kcal/$EBW^{0.75}$/day is obtained when MEI equals to HP. Using the same method, with the HP model as a function of MEI for grazing animals ($HP = 0.0717 \times e^{4.439 \times MEI}$), an ME_m value of 124.7 kcal/$EBW^{0.75}$/day is obtained, which is 11% higher than that obtained for feedlot. Therefore, it is suggested that after the k_m is calculated by the proposed equation and an ME_m value is obtained, by dividing the NE_m value by k_m, an addition of 11% should be made to the ME_m of cattle in pasture.

The higher ME_m observed for pasture raised cattle is a consequence of the greater use of energy for locomotion, forage apprehension and efficiency in the use of dietary energy. Animals under grazing conditions normally have at their disposal diets with a lower metabolizability than in feedlot, which, according to Garrett (1980), leads to a lower efficiency in the use of metabolizable energy for maintenance and gain.

Voluntary activities

Nutritional requirements have been determined for feedlot cattle due to the possibility of measuring the supplied feed and the metabolizable energy intake. Under this system, normal physical activities are considered in the estimate of heat production. These activities include lying and rising, chewing and rumination and the muscular activity to standing and walking. However, for animals raised on pasture, the locomotion activity is greater compared with feedlot animals. The CSIRO (2007) considers that animals on pasture spend more energy with ingestion activities than feedlot animals. This system assumes that the energy spent walking is 0.62 Kcal/Km for horizontal and 6.69 Kcal/Km for vertical locomotion. The system also assumes that the additional metabolizable energy intake, expressed in MJ, can be calculated by 0.0025 x DMI_p x (0.9 – DDM), where DMI_p is the dry matter intake (kg/day) of pasture and DDM is the dry matter pasture digestibility. When adopting those corrections, animals in pasture show maintenance requirements that are 10 to 20% greater than feedlot animals, depending on the topography of the land, the stocking rate and the availability and quality of pasture.

In the present study, only 6 of the 26 studies of the database were developed under pasture conditions. This group of animals was evaluated separately regarding nutritional requirements and, as observed before, there was an increase of 11% in the ME_m requirements of animals raised on pasture conditions. However, there still is great variability and lack of data about pasture raised cattle, which suggests that there is a lot to be done in this system. Experiments of comparative slaughter conducted in pasture are difficult to manage because the intake of pasture and supplement, as well as fecal excretion, must be estimated with the use of markers.

Most research has been developed to improve the methods to estimate the intake and excretion of animals in pasture (Ferreira et al., 2009). However more experiments are necessary to increase the number of repetitions to supply conditions for better statistical analyses, which will enable model the effect of grazing on the requirements for maintenance with greater precision.

Environmental effects

The main factors involved in determining thermal comfort are as follows: the environment (air temperature, air moisture, solar radiation and atmospheric pressure); the skin structure of the animal (thickness, thermal insulation, wind penetration, ventilation, emissivity, absorption and reflectivity); and body characteristics (body shape, size, surface area, area exposed to solar radiation, emissivity and epidermal absorption) (Silva, 2000). The thermoneutral zone, which limited by the critical minimum and maximum temperatures, is defined as the temperature range at which no additional expenditure of energy is needed to maintain body temperature.

In tropical conditions, the minimum environmental temperature is rarely below the critical minimum temperature. Thus, the stress from cold temperatures is not of great relevance in determining nutritional requirements.

However, the critical maximum temperature can be reached in tropical conditions. Under thermal stress from heat, dry matter intake is lesser. However, when the critical maximum temperature is surpassed for only a short period of the day, the intake might be recovered when the temperature is lower. Thermal stress from heat raises respiratory frequency, heart beat rate and panting, which increases the energy expenditure for the maintenance of body temperature. However, thermal stress from heat also decreases metabolic heat production, which makes the adoption of nutritional adjustments for this factor complex.

Nellore cattle have a higher tolerance to caloric stress than *Bos taurus* due to morphological factors such as: greater body surface area due to loose skin; short hair, which makes the loss of heat easier; a light hair color, which favors the reflection of solar radiation; dark skin, which lowers the damage caused by ultraviolet radiation; and intense sweating, which is the result of the larger number, size and activity of sweat glands.

ENERGY REQUIREMENTS FOR WEIGHT GAIN

The composition of empty body gain is the main driver of energy requirements for weight gain, which are estimated from retained energy in the body. What determines the composition of empty body gain is not the absolute body weight, but the weight relative to animal maturity.

The NRC (2000) estimates the net energy requirements for gain (**NE_g**) from the equivalent empty body weight (EQEBW) and from the desired empty body weight gain (EBG). The NRC equation for calculating the NE_g is the following: $NE_g = 0.0635 \times EQEBW^{0.75} \times EBG^{1.097}$. This equation was built considering a steer weighing 478 kg and with a body fat content of 28%. The NRC (2000) still recommends applying the 18% factor for more or for less to obtain the net energy requirements for weight gain of heifers and bulls, respectively.

The first version of BR-CORTE also recommended adjustments for gender. However, the retained energy of bulls was approximately 13% lesser than that for steers, which showed a retained energy 17.3% lesser than heifers:

Bulls	$NE_g = 0.0529 \times EBW^{0.75} \times EBG^{1.0996}$
Steers	$NE_g = 0.0608 \times EBW^{0.75} \times EBG^{1.0996}$
Heifers	$NE_g = 0.0735 \times EBW^{0.75} \times EBG^{1.0996}$

where EBW is the empty body weight and EBG is the empty body gain.

Chizzotti et al. (2008) recommended the following equation to predict NE_g:

$$NE_g = a \times EBW^{0.75} \times EBG^{1.070}$$

where EBW = empty body weight, kg; EBG = empty body weight gain; and *a* is equal to 0.0514, 0.0700, or 0.0771 for bulls, steers and heifers, respectively.

The authors did not evidence a genetic group effect on the net requirements for gain. The breed effect on energy requirements for gain may be attributed to the different adult weights and the precocity of fat deposition of the different breeds used for beef production. The different weights at maturity of the breeds will determine the different degrees of maturity of animals with the same absolute weight. Therefore, for animals with the same absolute weight and the same weight gain rate, higher energy concentrations are expected in the gain of animals from breeds with lower weight at maturity than animals from breeds with later maturity.

The exponents of EBG are close to the NRC's equation (1.097) and is comparable to that obtained for pure and crossbred Zebu (1.070). It is apparent that the requirements for gain of purebred and crossbred Zebu are somewhat inferior to those for pure taurines due to the lower fat content in the carcass (and the lower fat content in the EBG) of zebu and their crosses.

Using the updated BR-CORTE database and the EQEBW instead of the EBW used previously, only gender effect was evidenced ($P < 0.0001$) in the NE_g estimate. It is understood that the absence of the genetic group is coherent once the use of EQEBW adjusts the difference in size to maturity among breeds and, therefore, the genetic group effect. Equations were thus generated for animals on feedlot and pasture systems.

Feedlot:

Bulls	$NE_g = 0.053 \times EQEBW^{0.75} \times EBG^{1.095}$
Steers	$NE_g = 0.064 \times EQEBW^{0.75} \times EBG^{1.095}$
Heifers	$NE_g = 0.072 \times EQEBW^{0.75} \times EBG^{1.095}$
Pasture:	$NE_g = 0.052 \times EQEBW^{0.75} \times EBG^{1.062}$

where EQEBW is the equivalent empty body weight and EBG is the empty body weight gain.

It is evident that the intercept of the proposed equations for animals in pasture and for bulls under feedlot is quite close. This result is likely due to the predominance of bulls (80%) in pasture database. It is also clear that the exponent of EBG is higher for confined animals than for those on pasture. These animals were, on average, slaughtered with lower body weight than those under feedlot, besides being submitted to less energetic diets; thus, the equation suggests that there is a lower energy concentration in the gain of pasture raised cattle because the growth stage and diet provide a higher protein proportion in the EBG.

For the effects of gender, the NE_g requirement of steers was 20% greater than bulls and 12.5% lesser than heifers. This difference corresponds to the amplitude suggested in the previous version of BR-CORTE (2006) of 30% (20 + 12.5%). However, the present database has a greater amount of data than the previous one, thus providing greater confidence in the evaluations.

Metabolizable energy efficiency for weight gain

To convert the net energy requirements in metabolizable energy for gain, it is necessary to know the efficiency of the use of metabolizable energy for weight gain (k_g).

The k_g can be estimated as the slope of the regression of retained energy (RE) on the MEI for gain (Figure 2); however, a high variation of k_g values among experiments is observed.

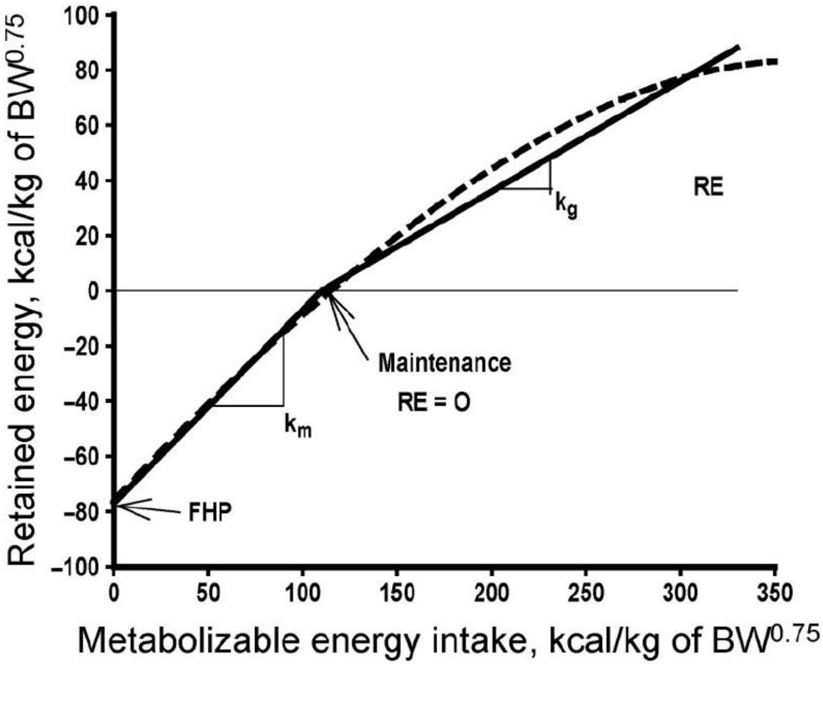

Figure 2 - Relationship between retained energy and metabolizable energy intake.

(Adapted from Ferrell and Oltjen, 2008).

The original BR-CORTE database was divided into animals receiving low or high concentrates (below or above 50% of concentrate in the diet, respectively). From this division, the k_g values were 0.35 for low energy diets and 0.47 for high energy diets. An overall analysis estimated the k_g value of approximately 0.38. Thus, the use of this value for all weight gain rates (i.e., different energy levels in the diet) could underestimate the metabolizable energy requirements for gain of low energy diets and overestimate it for high energy diets.

The retention of energy in the empty body occurs through protein and fat deposition. The efficiency of energy deposition in the form of fat is greater than that of protein (Owens et al., 1995). Therefore, the efficiency with which the energy is retained in the body (k_g) depends on the proportions of retained energy in the form of protein and fat. Because these proportions are variable, k_g cannot be constant. Thus, an estimate of k_g that is based on the gain composition is proposed.

Kielanowki (1965) suggested that the MEI could be represented by the sum of metabolizable energy for maintenance and the energy retained as fat and protein, as follows:

$$MEI = ME_m + RE_{fat}/k_{fat} + RE_{prot}/k_{prot}$$

where RE_{fat} and RE_{prot} represent the retained energy in the form of fat or protein (Mcal/day), respectively, and k_{fat} and k_{fat} represent their respective efficiencies of deposition.

Fat is the main form of animal energy reserve, and it has a caloric value of 9.367 kcal/g (Blaxter and Rook, 1953) while protein has 5.686 kcal/g (Garrett, 1958). Thus, the higher the percentage of protein in gain, the lower will be its energy concentration and vice versa, making the estimate of the percentage of retained energy as protein (%RE_p) possible as a function of the energy concentration in the EBG (RE, Mcal/kg of EBG).

From the model described above, Tedeschi et al. (2004) proposed the following equation to estimate k_g:

$$k_g = (k_{fat} \times k_{prot}) / [k_{prot} + (\%RE_p/100) \times (k_{fat} - k_{prot})]$$

where %RE_p is the energy proportion retained in the form of protein.

The Australian system (CSIRO, 2007) represents k_{prot} and k_{fat} as 45 and 75%, respectively, whereas Chizzotti et al. (2008) found values of 34 and 79%, respectively. However, the evaluation of this equation for estimating the k_g indicated overestimates (Marcondes, data not yet published).

To solve this problem, Marcondes et al. (2010b) evaluated the estimate for k_g from a direct relation with RE_P. Thus, the k_g was obtained from the relation between the RE and the MEI_g for each of the 25 studies, and the values that were found were related to several other variables (Figure 3).

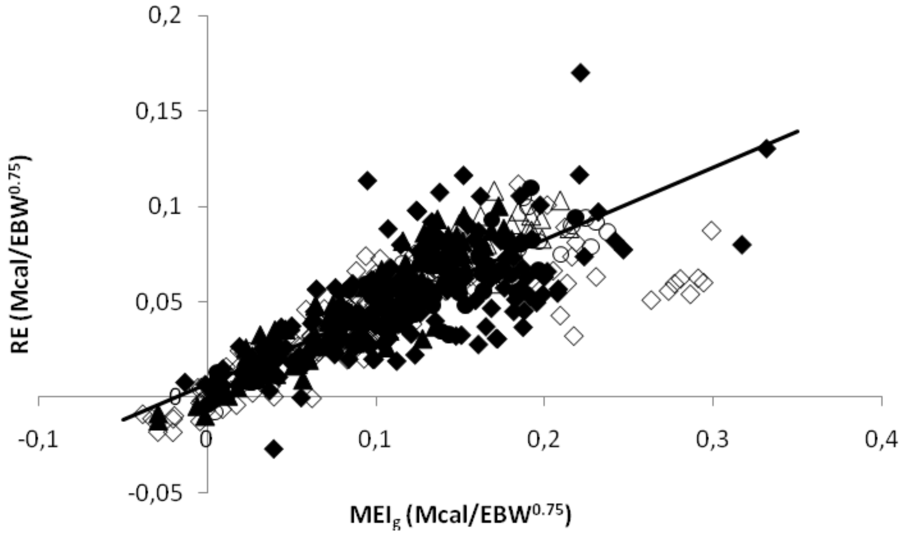

Figure 3 - Relation between retained energy (RE) and the MEI for gain (MEI_g) .The symbols represent data of bulls (▲, Δ), steers (◊,♦) and heifers (○, ●). The solid points represent Nellore animals, and the empty points represent crossbred *Bos indicus* x *Bos taurus* (Adapted from Marcondes et al., 2010b).

It was observed that the best variable to explain the k_g was the proportion of energy retained in the form of protein ($\%RE_p$). This variable had already been used in the models proposed by Tedeschi et al. (2004) and Chizzotti et al. (2008), and it is important to correlate the efficiency of gain with the composition of gain. The equation obtained by Marcondes et al. (2010b) was:

$$k_g = 0.327 / (0.539 + (\%RE_p/100))$$

It is clear that the model proposed by the authors is simpler than the previous model. However, for a practical application of this equation it is necessary to obtain a way of estimating the $\%RE_p$. Tedeschi et al. (2004) and Chizzotti et al. (2008) proposed exponential models to estimate the $\%RE_p$. Their respective equations are:

$RE_p = 0.0554 + 1.6939 \times e^{-0.5573 \times RE/EBG}$; and $RE_p = 10.1 + 166.7 \times e^{-0.660 \times RE/EBG}$.

Marcondes et al. (2010b), however, did not use the same model because, for any of the equations above, there would still be a retention in the form of protein even with the RE equal to zero. Thus, the authors used a potential model for describing the energy retention as protein, and obtained the following equation:

$$\%RE_p = 1.1404 \times (RE/EBG)^{-1.137}$$

There were no gender or genetic group effects on k_g. Nevertheless, the equations suggests the need of an evaluation of the results. Supposing there are two animals, one depositing 20 and the other depositing 60% of their energy as protein, estimates of 0.44 and 0.29 would be obtained for k_g, respectively, using the model proposed by Marcondes et al. (2010b), and k_g estimates of 0.67 and 0.47, respectively, would be obtained using the model proposed by Chizzotti et al. (2008). It is clear that there is an overestimation of k_g values in the latter model; therefore, the model proposed by Marcondes et al. (2010b) is adopted in the present BR-CORTE edition.

TABLES OF ENERGY REQUIREMENTS

From the determination of net energy requirements for maintenance and gain and their subsequent conversion into metabolizable energy requirements for maintenance and gain, it is possible to obtain the total metabolizable energy requirements (ME). Tables 5 and 6 show the summaries of all the equations that were used for estimating the total requirements of ME for Zebu purebred and crossbred of different genders in this edition of BR-CORTE.

Considering that DE is used with an average efficiency of 82%, it is possible to obtain the DE as ME/0.82. As many nutritionists are accustomed to formulate diets based on TDN requirements, the DE values were converted to TDN considering the relation of 4.409 kcal of DE / kg of TDN (NRC, 2000).

Tables 7, 8 and 9 depicts, respectively, the net energy for gain, the total metabolizable energy and the TDN requirements for Nellore of different gender. Tables 10, 11 and 12 show the respective data for crossbred animals. Table 13 shows the net energy for gain and the total metabolizable energy and the TDN requirements for animals under pasture system.

Table 5 - Summary of models for energy requirements of purebred and crossbred Nellore animals of three genders in feedlot system

Item	Equations	Unit
EBW	0.895 × SBW	kg
EBG	Nellore: 0.935 × ADG Cruzados: 0.966 × ADG	kg/day
EQEBW	Nellore: (EBW/430)× 440 Crossbred:(EBW / 455)×440	kg
NE_m	$0.0742 \times EBW^{0.75}$	Mcal/day
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
$\%RE_p$	$1.1404 \times (RE/EBG)^{-1.137}$	%
k_g	$0.327 / (0.539 + (\%RE_p/100))$	%
k_m	Nellore: $0.513 + 0.173 \times k_g + 0.100 \times EBG$ Crossbred: $0.513 + 0.173 \times k_g + 0.073 \times EBG$	%
ME_m	NE_m/k_m	Mcal/day
ME_g	NE_g/k_g	Mcal/day
ME_t	$ME_m + ME_g$	Mcal/day
TDN	ME_t /0.82/4.409	kg/day

Table 6 - Summary of models of energy requirements of purebred and crossbred Nellore animals on pasture system

Item	Equations	Unit
EBW	0.863 × SBW	kg
EBG	0.955 × ADG	kg/day
EQEBW	(EBW/430)× 440	kg
NE_m	$0.0717 \times EBW^{0.75}$	Mcal/day
NE_g	$0.052 \times EQEBW^{0.75} \times EBG^{1.062}$	Mcal/day
$\%RE_p$	$1.1404 \times (RE/EBG)^{-1.137}$	%
k_g	$0.327 / (0.539 + (\%RE_p/100))$	%
k_m	$0.513 + 0.173 \times k_g + 0.100 \times EBG$	%
ME_m	$1,11 \times NE_m/k_m$	Mcal/day
ME_g	NEg/k_g	Mcal/day
ME_t	$ME_m + ME_g$	Mcal/day
TDN	ME_t /0.82/4.409	kg/day

Thus, 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
- $\%RE_p = 1.1404 \times (RE/EBG)^{-1.137} = 1.1404 \times (4.12/0.935)^{-1.137} = 0{,}2112 = 21.12\%$
- $k_g = 0.327 / (0.539 + (\%RE_p/100)) = 0.327 / (0.539 + (21.12/100)) = 0.44$
- $ME_g = NE_g / k_g = 4.12 / 0.44 = 9.36$ Mcal /day
- $ME_m = 74.2 \times EBW^{0.75} = 74.2 \times 358^{0.75} = 6106.83$ kcal/ day = 6.11 Mcal / day
- $k_m = 0.513 + 0.173 \times k_g + 0.100 \times EBG = 0.513 + 0{,}173 \times 0.44 + 0.100 \times 0.935 = 0.68$
- $ME_m = NE_m / k_m = 6.11 / 0.68 = 8.99$ Mcal / day
- $ME_t = ME_m + ME_g = 9.36 + 8.99 = 18.35$ Mcal / day
- $DE = ME_t / 0.82 = 18.35 / 0.82 = 22.38$ Mcal / day
- TDN = DE / 4.409 = 22.38/ 4.409 = 5.08 kg / day

To obtain the required TDN concentration in dry matter basis, the TDN requirement in kg (5.08 kg/day) should be divided by the dry matter intake, estimated from the equations presented in chapter 1 of this BR-CORTE edition.

Table 7 - Net energy requirements for weight gain, expressed in Mcal/day, of purebred Nellore cattle of different gender and with different weights and weight gain rates in feedlot

Weight gain	Body Weight (kg)						
(kg/day)	150	200	250	300	350	400	450
				Bulls			
0.50	0.93	1.15	1.36	1.56	1.75	1.93	2.11
0.75	1.44	1.79	2.11	2.42	2.72	3.01	3.29
1.00	1.98	2.45	2.90	3.32	3.73	4.12	4.50
1.25	2.52	3.13	3.70	4.24	4.76	5.27	5.75
1.50	3.08	3.82	4.52	5.18	5.82	6.43	7.02
				Steers			
0.50	1.12	1.39	1.64	1.88	2.11	2.33	2.55
0.75	1.74	2.16	2.55	2.93	3.29	3.63	3.97
1.00	2.39	2.96	3.50	4.01	4.50	4.98	5.44
1.25	3.05	3.78	4.47	5.12	5.75	6.36	6.95
1.50	3.72	4.62	5.46	6.26	7.02	7.76	8.48
				Heifers			
0.50	1.26	1.56	1.85	2.12	2.37	2.63	2.87
0.75	1.96	2.43	2.87	3.29	3.70	4.09	4.46
1.00	2.68	3.33	3.94	4.51	5.07	5.60	6.12
1.25	3.43	4.25	5.03	5.76	6.47	7.15	7.81
1.50	4.19	5.19	6.14	7.04	7.90	8.74	9.54

Table 8 - Total requirements (maintenance + gain) of metabolizable energy (ME), expressed in Mcal/day of purebred Nellore cattle of different gender and with different weights and weight gain rates in feedlot

Weight gain (kg/day)	Body Weight (kg)						
	150	200	250	300	350	400	450
				Bulls			
0.50	7.80	9.23	10.60	11.81	13.03	14.19	15.22
0.75	9.23	10.78	12.15	13.62	14.84	16.26	17.59
1.00	10.63	12.23	14.03	15.54	17.00	18.35	19.81
1.25	12.13	13.95	15.62	17.37	19.22	20.59	22.17
1.50	13.46	15.65	17.55	19.46	21.09	22.98	24.74
				Steers			
0.50	8.02	9.42	10.91	12.29	13.43	14.73	15.96
0.75	9.55	11.26	12.82	14.26	15.84	17.15	18.56
1.00	11.20	13.01	14.85	16.57	18.12	19.69	21.24
1.25	12.96	14.88	16.77	18.57	20.55	22.44	24.18
1.50	14.40	16.89	18.88	20.97	23.16	24.88	26.68
				Heifers			
0.50	8.23	9.76	11.21	12.51	13.90	15.15	16.40
0.75	9.81	11.66	13.17	14.93	16.40	17.96	19.25
1.00	11.61	13.67	15.47	17.26	19.02	20.53	22.16
1.25	13.52	15.56	17.83	19.73	21.54	23.51	25.33
1.50	15.10	17.70	20.16	22.38	24.37	26.47	28.48

Table 9 - Total requirements (maintenance + gain) of total digestible nutrients (TDN) expressed in kg/day of purebred Nellore cattle of different gender and with different weights and weight gain rates in feedlot

Weight gain (kg/day)	Body Weight (kg)						
	150	200	250	300	350	400	450
				Bulls			
0.50	2.16	2.55	2.93	3.27	3.60	3.92	4.21
0.75	2.55	2.98	3.36	3.77	4.10	4.50	4.87
1.00	2.94	3.38	3.88	4.30	4.70	5.08	5.48
1.25	3.36	3.86	4.32	4.80	5.32	5.70	6.13
1.50	3.72	4.33	4.85	5.38	5.83	6.36	6.84
				Steers			
0.50	2.22	2.61	3.02	3.40	3.71	4.07	4.41
0.75	2.64	3.11	3.55	3,94	4.38	4.74	5.13
1.00	3.10	3.60	4.11	4.58	5.01	5.45	5.87
1.25	3.58	4.12	4.64	5.14	5.68	6.21	6.69
1.50	3.98	4.67	5.22	5.80	6.41	6.88	7.38
				Heifers			
0.50	2.28	2.70	3.10	3.46	3.84	4.19	4.54
0.75	2.71	3.23	3.64	4.13	4.54	4.97	5.32
1.00	3.21	3.78	4.28	4.77	5.26	5.68	6.13
1.25	3.74	4.30	4.93	5.46	5.96	6.50	7.01
1.50	4.18	4.90	5.58	6.19	6.74	7.32	7.88

Table 10 - Net energy requirements for weight gain expressed in Mcal/day of crossbred Zebu cattle of different gender and with different weights and weight gain rates in feedlot

Weight gain (kg/day)	Body weight (kg)						
	150	200	250	300	350	400	450
				Bulls			
0.50	0.92	1.14	1.35	1.55	1.73	1.92	2.09
0.75	1.43	1.8	2.10	2.41	2.71	2.99	3.27
1.00	1.96	2.44	2.88	3.30	3.71	4.10	4.47
1.25	2.51	3.11	3.68	4.22	4.73	5.23	5.71
1.50	3.06	3.80	4.49	5.15	5.78	6.38	6.97
				Steers			
0.50	1.11	1.38	1.63	1.87	2.09	2.32	2.53
0.75	1.73	2.15	2.54	2.91	3.27	3.61	3.95
1.00	2.37	2.94	3.48	3.99	4.47	4.95	5.40
1.25	3.03	3.76	4.44	5.09	5.72	6.32	6.90
1.50	3.69	4.58	5.42	6.21	6.98	7.71	8.42
				Heifers			
0.50	1.25	1.55	1.83	2.10	2.36	2.60	2.85
0.75	1.95	2.42	2.86	3.27	3.68	4.06	4.44
1.00	2.67	3.31	3,91	4.48	5.03	5.56	6.08
1.25	3.41	4.23	5,00	5.73	6.43	7.11	7.76
1.50	4.16	5.16	6.10	6.99	7.85	8.67	9.47

Table 11 - Total requirements (maintenance + weight gain) of metabolizable energy (ME) expressed in Mcal/day of crossbred Zebu cattle, of different gender and with different weights and weight gain rates in feedlot

Weight gain (kg/day)	Body weight (kg)						
	150	200	250	300	350	400	450
				Bulls			
0.50	7.95	9.30	10.68	11.91	13.12	14.42	15.62
0.75	9.34	11.09	12.49	13.99	15.24	16.50	17.85
1.00	10.90	12.64	14.18	15.82	17.19	18.79	20.27
1.25	12.28	14.39	16.08	17.89	19.50	21.15	22.50
1.50	13.93	15.90	18.13	20.01	21.76	23.36	25.02
				Steers			
0.50	8.16	9.68	11.00	12.39	13.76	14.86	16.09
0.75	9.82	11.42	13.05	14.62	16.06	17.57	18.85
1.00	11.55	13.32	15.09	16.73	18.52	20.02	21.60
1.25	13.10	15.31	17.23	19.08	20.83	22.73	24.49
1.50	14.85	17.00	19.44	21.57	23.40	25.49	27.44
				Heifers			
0.50	8.37	9.82	11.38	12.82	14.00	15.35	16.65
0.75	10.07	11.97	13.51	15.12	16.81	18.04	19.51
1.00	11.93	13.86	15.81	17.63	19.29	21.09	22.63
1.25	13.59	16.00	17.94	19.97	22.10	24.12	25.98
1.50	15.55	18.16	20.41	22.56	24.96	26.79	28.86

Table 12 - Total requirements (maintenance + gain) of total digestible nutrients (TDN) expressed in kg/day of crossbred Zebu cattle of different gender and with different weights and weight gain rates in feedlot

Weight gain	Body weight (kg)						
(kg/day)	150	200	250	300	350	400	450
				Bulls			
0.50	2.20	2.57	2.95	3.29	3.63	3.99	4.32
0.75	2.58	3.07	3.45	3.87	4.22	4.56	4.94
1.00	3.01	3.50	3.92	4.38	4.75	5.20	5.61
1.25	3.40	3.98	4.45	4.95	5.39	5.85	6.22
1.50	3.85	4.40	5.01	5.53	6.02	6.46	6.92
				Steers			
0.50	2.26	2.68	3.04	3.43	3.81	4.11	4.45
0.75	2.72	3.16	3.61	4.04	4.44	4.86	5.21
1.00	3.19	3.68	4.17	4.63	5.12	5.54	5.97
1.25	3.62	4.23	4.77	5.28	5.76	6.29	6.77
1.50	4.11	4.70	5.38	5.97	6.47	7.05	7.59
				Heifers			
0.50	2.32	2.72	3.15	3.55	3.87	4.25	4.61
0.75	2.79	3.31	3.74	4.18	4.65	4.99	5.40
1.00	3.30	3.83	4.37	4.88	5.34	5.83	6.26
1.25	3.76	4.43	4.96	5.52	6.11	6.67	7.19
1.50	4.30	5.02	5.65	6.24	6.90	7.41	7.98

Table 13 - Net energy requirements for gain, total requirements (maintenance + gain) of metabolizable energy expressed in Mcal/day and TDN (kg/day) of Nellore bulls and steers with different weights and weight gain rates on pasture system

Weight gain	Body weight (kg)						
(kg/day)	150	200	250	300	350	400	450
				Net Energy for Gain (Mcal/day)			
0.50	0.93	1.15	1.36	1.56	1.75	1.93	2.11
0.75	1.42	1.77	2.09	2.40	2.69	2.97	3.25
1.00	1.93	2.40	2.84	3.25	3.65	4.03	4.41
1.25	2.45	3.04	3.59	4.12	4.63	5.11	5.59
1.50	2.97	3.69	4.36	5.00	5.61	6.21	6.78
				Metabolizable Energy (Mcal/day)			
0.50	8.03	9.49	10.86	12.16	13.41	14.61	15.78
0.75	9.41	11.00	12.50	13.93	15.31	16.63	17.92
1.00	10.82	12.56	14.20	15.76	17.26	18.72	20.13
1.25	12.26	14.14	15.93	17.63	19.27	20.85	22.39
1.50	13.72	15.76	17.68	19.53	21.31	23.03	24.71
				TDN (kg/day)			
0.50	2.22	2.62	3.00	3.36	3.71	4.04	4.36
0.75	2.60	3.04	3.46	3.85	4.23	4.60	4.96
1.00	2.99	3.47	3.93	4.36	4.78	5.18	5.57
1.25	3.39	3.91	4.40	4.88	5.33	5.77	6.19
1.50	3.79	4.36	4.89	5.40	5.89	6.37	6.83

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