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Nutrient requirements for lactating beef cows and their calves

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INTRODUCTION

Brazil has approximately 200 million cattle (ANUALPEC, 2015), with around of 65 million being cows (females aged above three years). In addition, most of these cows are from Zebu cattle (*Bos taurus indicus*) and their crosses, responsible for the supply of all animals for the beef production chain.

In beef cattle production, the breast-feeding phase is important for the beef production chain to provide future animals that will be utilized for other phases of the production system; additionally, it is characterized by the use of a large number of animals, with 31% of the production herd being represented by beef cows (Calegare, 2004). Moreover, 70% of the energy required for beef production is utilized for functions involved with cow maintenance (Ferrell and Jenkins, 1985). Thus, approximately 50% of the energy required to raise an animal until slaughter is utilized for cow maintenance.

In this context, Brazilian livestock has been pressured to develop an efficient, competitive, and continuous beef production program based on the areas currently utilized for livestock, which are mandatorily based on reduction of the production cycle. Thereby, the production systems have intensified to reduce the age of animals at slaughter, increasing the amount and quality of products offered. In this way, knowledge of the potential dry matter intake (DMI) of cows and calves becomes essential for adequate planning and technology used to reach production targets established in the system.

During the breast-feeding phase, the correct measurement of milk yield (MY) becomes indispensable because this parameter represents the amount of nutrients that the cows are secreting into the milk. Furthermore, this estimate will be considered to calculate the amount of nutrients that the calf is consuming from the milk, which will be considered to meet nutrient requirements of these animals. Milk yield can be measured directly and indirectly; the most common methods are manual milking (Gifford, 1953), weighing calves before and after suckling (Knapp and Black, 1941), mechanical milking after oxytocin use (Anthony et al., 1959), and evaluation of the deuterium monoxide content of milk (Freetly et al., 2006). Then, beyond an understanding of the DMI for animals, MY will influence calf performance and consequently body weight (BW) at weaning. In this context, the second edition of the BR-CORTE utilized the recommendation of Henriques et al. (2011) which evaluated different models to estimate MY of lactating Nellore cows. However, the equation was not validated under tropical conditions.

The metabolizable energy intake (MEI) that does not incur changes in energy in the body will influence the dietary energy required for maintenance, meaning that this parameter is considered a characteristic with moderate to high heritability (Carstens et al., 1988). Thereby, energy inefficiency, from 60 to 70% of the total energy required for maintenance of the animals (Bottje and Carstens, 2009), has been attributed to protein turnover, ion pumps (Na^+ and K^+) and the uncoupling of oxidative phosphorylation in the mitochondria. Thus, the selection of animals that have lower nutrient requirements could be adopted, with the aim of obtaining more efficient animals.

The energy requirements of the animal correspond to the sum of the needs for maintenance and production, which can be divided into energy required for growth, lactation, and pregnancy (Webster, 1979).

However, few studies (Fonseca, 2012a; b) have been conducted in Brazil to estimate the nutrient requirements of animals during the breast-feeding phase, or those of lactating cows and suckling calves. Thereby, from the knowledge of MY and nutrient requirements of calves, the amount of energy and protein secreted by milk can be determined, which allows estimating the moment that milk does not provide enough nutrients and, thus, the exact moment for calf supplementation.

In this chapter, the discussion about equations developed to estimate DMI and milk production and composition of lactating Nellore cows will be presented, as well as the DMI of suckling Nellore calves. Also, the requirements of energy, protein, and minerals will be presented for lactating Zebu cows and their calves.

DRY MATTER INTAKE OF LACTATING BEEF COWS

The last edition of the BR-CORTE (2010) utilized the constant value of 2.39% BW for DMI of lactating Zebu cows during the first six months of lactation suggested by Fonseca (2009). However, the use of constant values does not estimate DMI of lactating cows accurately because the nutrient requirements of these animals reduce when lactation advances. Thereby, Costa e Silva (2015) evaluated five models to estimate the DMI (g/kg BW) of Nellore cows during the seven-month lactation period and observed that the adjusted equation using the model proposed by Wilmink (1987) added to the average daily gain (ADG) provided better estimates (Figure 11.1).

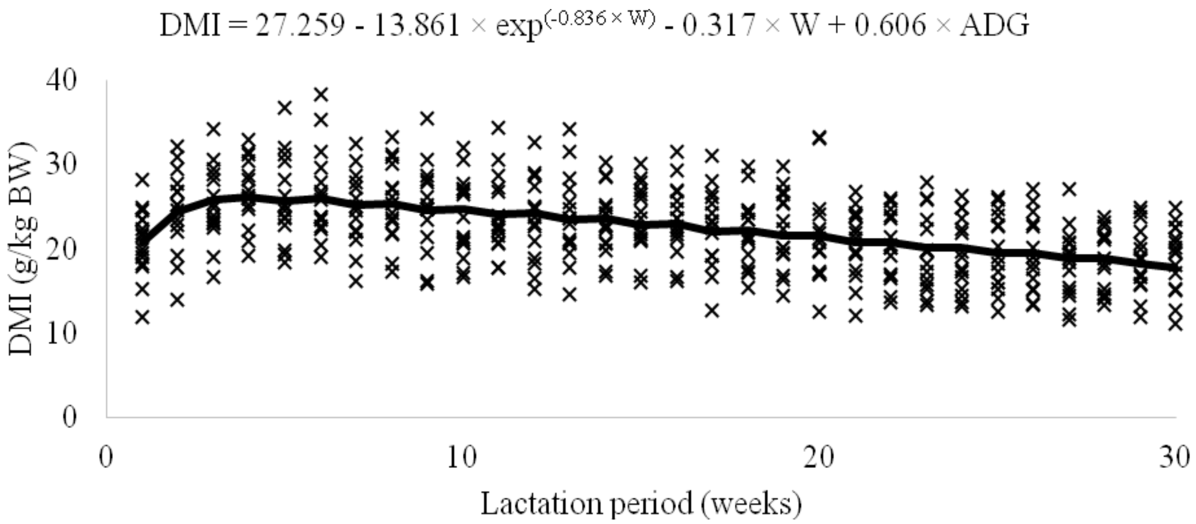

Figure 11.1 - Dry matter intake (g/BW) of Zebu cows during the lactation period.

Thus, the equation proposed by Costa e Silva (2015) was:

$$DMI\ (g/BW) = 27.259 - 13.861 \times \exp^{(-0.836 \times W)} - 0.317 \times W + 0.606 \times ADG,$$

where: DMI = dry matter intake, W = week of lactation, ADG = average daily gain (kg/d).

Considering the recommendation of BR-CORTE (2010), only values predicted in the beginning of lactation from the equation proposed by Costa e Silva (2015) are close to the mean recommended by the BR-CORTE (2010). However, when the last 4 weeks of lactation are considered, the difference between the recommendation of the BR-CORTE (2010) and the values predicted by the equation of Costa e Silva (2015) was 1.5 kg/d (6.0 *vs*. 7.5 kg/d).

Furthermore, Costa e Silva (2015) verified that the equation using the model proposed by Wilmink (1987) added to ADG correctly estimated the DMI of lactating Zebu cows raised on pasture from an independent database that contained a total of 120 observations (Table 11.1).

Table 11.1 - Descriptive statistics of the independent database utilized to evaluate the prediction equations for dry matter intake (DMI) and milk yield of beef cows

Study	Item	n	Mean	SD[1]	Maximum	Minimum
Lopes (2012)	Week of lactation	-	26.5	5.45	37.0	12.0
	Milk yield	143	6.97	1.58	9.99	4.24
	Total DMI	32	11.8	2.35	17.0	7.95
	Body weight	32	481	50.6	558	359
	Average daily gain	32	-0.34	0.35	0.22	-1.38
Cardenas (2012)	Week of lactation	-	28.1	6.38	40.0	12.0
	Milk yield	170	7.00	1.36	9.87	4.21
	Total DMI	60	12.9	1.45	16.7	9.94
	Body weight	60	450	51.6	567	362
	Average daily gain	60	0.20	0.09	0.40	-0.04
Márquez (2013)	Week of lactation	-	27.3	8.63	41.0	10.0
	Milk yield	61	6.49	1.64	9.40	3.37
	Total DMI	28	15.5	3.04	22.9	8.49
	Body weight	28	499	44.6	595	428
	Average daily gain	28	0.05	0.11	0.28	-0.17
Lopes (2015)	Week of lactation	-	8.05	2.65	12.0	3.00
	Milk yield	37	8.47	1.46	10.8	5.79

[1] SD = standard deviation; Adapted from Costa e Silva (2015).

After evaluations, Costa e Silva (2015) observed that the intercept and slope of the equation were not different from 0 and 1, respectively. Moreover, the mean square error of the prediction was close to zero, with this error being associated with random errors (92.1%; Table 11.2). Thus, in this edition of BR-CORTE is recommended that total DMI of lactating beef cows could be estimated from the following equation:

$$DMI\ (g/kg\ BW) = 27.259 - 13.861 \times \exp^{(-0.836 \times W)} - 0.317 \times W + 0.606 \times ADG.$$

MILK YIELD AND COMPOSITION OF BEEF COWS

The second edition of the BR-CORTE was based on the study developed by Henriques et al. (2011), suggesting an equation to estimate the milk yield of Zebu cows. These authors evaluated five models and recommended that the model described by Jenkins and Ferrell (1984) modified by Detmann (personal communication) was the best model that adjusted data. However, due to the lack of a model developed for Zebu cattle, the equation suggested by Henriques et al. (2011) was adopted:

$$MY = 5.9579 + 0.4230 \times W \times \exp^{(0.1204 \times W)},$$

where MY = milk yield and W = week of lactation. Nevertheless, Costa e Silva (2015) evaluated five models available in the literature to estimate the MY of Zebu cows during the seven-months lactation. In this study, the cows received a high-roughage diet (85% on DM basis) to simulate a diet at pasture receiving supplementation. Thereby, the equation that presented the better estimates was that adjusted using the model proposed by Cobby and Le Du (1978; Figure 11.2).

Table 11.2 - Mean (kg) and descriptive statistics for the relationship between observed and predict values of dry matter intake (DMI) and milk yield of lactating beef cows and DMI of roughage and concentrate of suckling beef calves

Item	Total DMI for cows		Milk yield				DMI of roughage and concentrate for calves	
	OBS[1]	Wilmink (1987) with ADG[2]	OBS[1]	Cobby and Le Du (1978)[3]	BR-CORTE (2010)[4]	NRC (1996)[5]	OBS[1]	BR-CORTE (2016)[6]
Mean	12.1	11.7	7.04	7.05	6.5	3.49	2.51	2.34
SD[7]	2.28	1.36	1.57	0.58	0.32	1.98	0.64	0.34
Maximum	17.0	14.0	10.8	8.57	7.25	8.00	3.99	3.37
Minimum	7.95	8.94	3.37	5.98	6.08	0.83	0.99	1.35
R	-	0.38	-	0.39	0.15	0.15	-	0.44
CCC[8]	-	0.33	-	0.65	0.14	0.13	-	0.33
Regression								
Intercept								
Estimate	-	4.49	-	-0.42	-5.29	5.97	-	0.55
SE	-	2.88	-	0.88	1.45	0.15	-	0.29
P-value[9]	-	0.13	-	0.64	< 0.001	< 0.001	-	0.054
Slope								
Estimate	-	0.65	-	1.06	1.9	0.31	-	0.85
SE	-	0.25	-	0.12	0.22	0.04	-	0.12
P-value[10]	-	0.16	-	0.63	< 0.001	< 0.001	-	0.24
MSEP[11]	-	4.68	-	2.09	2.47	16.6	-	0.40
Mean bias	-	0.15	-	0.00	0.30	12.6	-	0.04
Systematic bias	-	0.22	-	0.01	0.08	1.86	-	0.002
Random errors	-	4.31	-	2.08	2.09	3.79	-	0.35

[1]OBS = observed values; [2]Wilmink (1987) with ADG = values predicted by the equation generated from the model proposed by Wilmink (1987) added to average daily gain (ADG); [3]Cobby and Le Du (1978) = values predicted by the equation generated from the model proposed by Cobby and Le Du (1978); [4]BR-CORTE (2010) = values predicted by the equation suggested by Valadares Filho et al. (2010); [5]NRC (1996): milk yield = week/(0.3911 × $\exp^{(0.1176 \times \text{week})}$); [6]BR-CORTE (2016) = values predicted by the equation proposed by Costa e Silva (2015); [7] SD = standard deviation; [8]CCC = concordance correlation coefficient; [9]H_0: $\beta_0 = 0$; [10]H_0: $\beta_1 = 1$; [11]MSEP = mean square error of prediction.

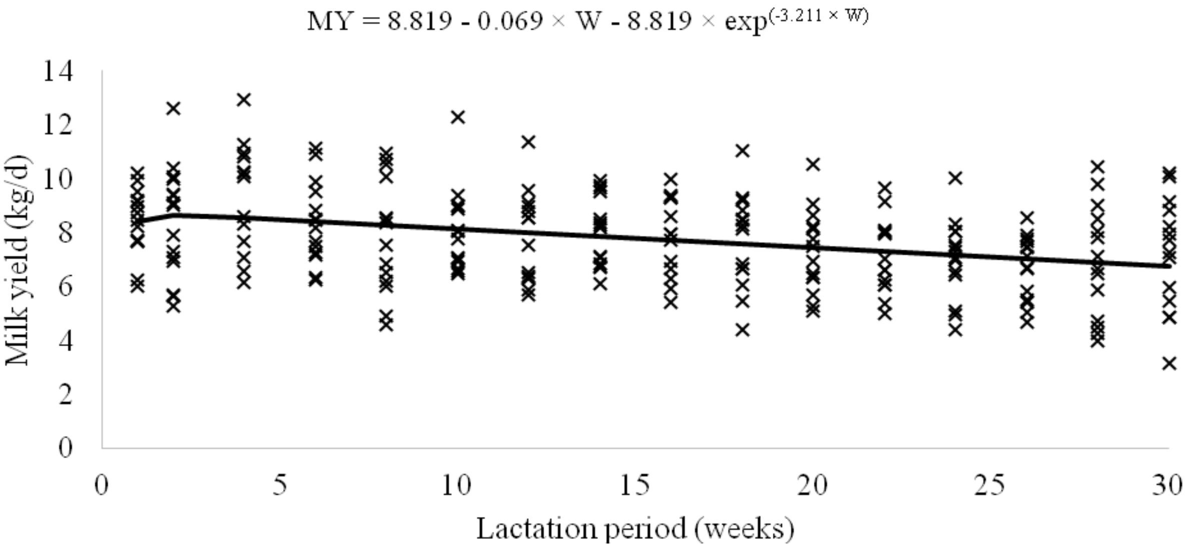

Figure 11.2 - Relationship between milk yield and week of lactation for lactating Zebu cows.

Furthermore, Costa e Silva (2015) evaluated whether the equations proposed by the BR-CORTE (2010), NRC (1996), and Cobby and Le Du (1978), correctly estimated the MY of Nellore cows raised on pasture of *Urochloa spp*. For that, an independent database was developed that contained 411 observations from 4 experiments conducted in the Beef Cattle sector of the Animal Science Department at *Universidade Federal de Viçosa* (Table 11.1).

After evaluation, Costa e Silva (2015) verified that the equation suggested by the model proposed by Cobby and Le Du (1978) had the better estimate as it was the unique equation that correctly estimated the MY of Nellore cows, presenting greater CCC (0.65) and lower mean square error of prediction (2.09), with 99.5% of this error being associated with random errors (Table 11.2). Thus, in this edition of BR-CORTE (2016) suggests the following equation to estimate milk yield of beef cows:

$$MY = 8.819 - 0.069 \times W - 8.819 \times \exp^{(-3.211 \times W)}.$$

The BR-CORTE (2010) utilized data from Fonseca (2009) to milk composition of Nellore cows. However, this recommendation discarded the variation that occurs through lactation in the concentration of milk components, considering only an average for each component during the entire lactation period. Moreover, mineral composition of the milk of Nellore cows was not presented in the last edition of the BR-CORTE (2010).

Then, Costa e Silva et al. (2015a) evaluated the milk composition of multiparous Nellore cows and verified that the percentage of total solids, lactose, and fat do not vary while protein increases through lactation. Thus, these authors suggested that the milk composition of Nellore cows would have an average percentage of 15.0% total solids, 4.59% lactose, and 5.61% fat, while protein would increase from 3.6%, at the beginning of lactation until 112 days, to 3.9%, at 7 months of lactation. The values were close to those recommended by the last edition of the BR-CORTE (2010), with an exception for fat content (5.61 *vs.* 3.88%). These greater values found by Costa e Silva et al. (2015a) can be attributed to a greater supply of roughage provided in the diet which possibly stimulated acetate production and thus caused a greater amount of substrate for *de novo* fat synthesis in the mammary gland. Furthermore, Costa e Silva et al. (2015a) also evaluated mineral milk composition of Zebu cows and considered that the average concentrations would be 1.11% Ca, 0.76% P, 0.20% Na, 0.25% S, 2.29 ppm Co, 3.20 ppm Cr, 29.9 ppm Fe, and 1.40 ppm Mn (Table 11.3).

Table 11.3 - Milk composition of Zebu cows during lactation

Component	Days of lactation							SEM	*P*-value
	28	56	84	112	140	168	196		
Total solids (%)	14.5	14.7	14.8	14.9	15.1	15.4	15.6	0.40	0.13
Protein (%)	3.57[c]	3.50[c]	3.54[c]	3.62[c]	3.75[b]	3.87[a]	3.94[a]	0.10	<0.001
Lactose (%)	4.58	4.66	4.63	4.62	4.60	4.52	4.48	0.10	0.05
Fat (%)	5.20	5.44	5.58	5.53	5.65	5.90	5.98	0.40	0.44
Ca (g/kg)	1.13	1.10	1.10	1.10	1.12	1.11	1.10	0.03	0.46
P (g/kg)	0.81[a]	0.74[b]	0.73[b]	0.76[ab]	0.77[ab]	0.77[ab]	0.76[ab]	0.02	0.01
Mg (g/kg)	0.06[c]	0.07[c]	0.07[c]	0.07[bc]	0.08[ab]	0.08[a]	0.08[a]	0.01	<0.001
K (g/kg)	0.71[ab]	0.70[ab]	0.71[ab]	0.73[a]	0.73[ab]	0.69[ab]	0.65[b]	0.03	0.04
Na (g/kg)	0.22[a]	0.20[b]	0.19[b]	0.19[b]	0.19[b]	0.19[b]	0.20[ab]	0.01	<0.001
S (g/kg)	0.26	0.24	0.25	0.25	0.26	0.26	0.26	0.01	0.08
Co (ppm)	2.32[ab]	2.58[a]	1.99[b]	2.20[ab]	2.48[ab]	2.16[ab]	2.28[ab]	0.20	0.03
Cr (ppm)	3.19	3.33	3.24	3.03	3.28	3.27	3.05	0.20	0.12
Cu (ppm)	3.01[a]	2.28[b]	1.98[b]	1.78[b]	1.73[b]	1.55[b]	1.54[b]	0.20	<0.001
Fe (ppm)	27.9	29.9	27.4	29.3	30.1	32.5	32.0	3.1	0.58
Mn (ppm)	1.47	1.26	1.24	1.36	1.47	1.53	1.47	0.2	0.21
Zn (ppm)	41.1[a]	35.5[b]	34.1[b]	33.9[b]	34.6[b]	34.7[b]	33.8[b]	1.8	<0.001

Adapted from Costa e Silva et al. (2015a).

DRY MATTER INTAKE OF SUCKLING BEEF CALVES

The last edition of the BR-CORTE (2010) recommended the constant value of 2.35% BW for total DMI of suckling Zebu calves during the first six months of age; this recommendation was from the study conducted by Fonseca (2009). However, Costa e Silva (2015) evaluated five models available in the literature to estimate the DMI of roughage and concentrate for Zebu calves during the breast-feeding phase. Also, knowing milk intake from the MY of cows and multiplying it by its DM content, we can obtain DMI from milk. Thereby, from the sum of DMI of milk and solid feedstuffs, we can access the total DMI of calves during the breast-feeding period. Thus, in this edition of the BR-CORTE, the following equation proposed by Costa Silva (2015) was adopted to estimate dry matter intake of roughage and concentrate for suckling beef calves:

$$DMIrc = 0.353 - 0.532 \times DMImilk + 0.01065 \times BW + 0.3497 \times ADG,$$

where DMIrc = dry matter intake of roughage and concentrate (kg/d), DMImilk = dry matter intake of milk (kg/d), BW = body weight (kg), ADG = average daily gain (kg/d). Additionally, from an independent database that contained 232 observations from 5 experiments conducted on pasture (Table 11.4), this equation was evaluated, resulting in the correct estimate of DMI of roughage and concentrate of suckling beef calves (Table 11.2). So, this equation is recommended by this edition of BR-CORTE (2016).

Table 11.4 - Descriptive statistics of the independent database utilized to predict dry matter intake of roughage and concentrate of suckling beef calves

Study	Item	n	Mean	SD[1]	Maximum	Minimum
Lopes (2012)	Age (d)	-	170	-	-	-
	DMI of concentrate	53	0.63	0.32	0.80	0.00
	DMI of roughage	53	2.02	0.59	3.34	0.79
	Body weight	53	188	31.0	256	123
	Average daily gain	53	0.85	0.12	1.14	0.64
Cardenas (2012)	Age (d)	-	192	33.2	245	120
	DMI of concentrate	62	0.46	0.20	0.97	0.04
	DMI of roughage	62	1.86	0.47	3.04	0.88
	Body weight	62	217	30.2	285	154
	Average daily gain	62	0.67	0.09	0.92	0.42
Márquez (2013)	Age (d)	-	150	-	-	-
	DMI of concentrate	28	1.08	0.56	2.63	0.28
	DMI of roughage	28	2.17	1.15	6.31	0.77
	Body weight	28	202	21.6	255	151
	Average daily gain	28	0.94	0.09	1.13	0.74
Lopes (2015)	Age (d)	-	190	-	-	-
	DMI of concentrate	42	0.84	0.61	1.62	0
	DMI of roughage	42	2.01	0.41	3.21	1.38
	Body weight	42	203	29.0	264	148
	Average daily gain	42	0.84	0.12	1.14	0.56
Martins (2016)	Age (d)	-	182	-	-	-
	DMI of concentrate	47	0.75	0.63	2.79	0.00
	DMI of roughage	47	2.32	1.05	5.63	1.00
	Body weight	47	212	28.1	296	161
	Average daily gain	47	0.81	0.17	1.08	0.43

[1] SD = standard deviation

ENERGY REQUIREMENTS FOR LACTATING BEEF COWS

The calculations utilized for nutrient requirements of lactating Zebu cows and their calves followed the same recommendations suggested in previous chapters. Due to the lack of experiments using lactating beef cows and their calves since the last edition of the BR-CORTE, in 2010, the nutrient requirements of these animals were based on the experiment conducted by Fonseca (2009).

The relationship between empty body weight (EBW) and shrunk body weight (SBW) of lactating cows followed the recommendation from Chapter 1:

$$EBW = 0.8507 \times SBW^{1.0002},$$

and the relationship between empty body gain (EBG) and ADG was considered as 0.936. Accordingly explained in the chapter of energy requirements for beef cattle, heat production (HP) was indirectly obtained by the difference between metabolizable energy intake (MEI) and retained energy (RE), which were determined by comparative slaughter techniques and energy secreted in the milk. Thereby, the net energy required for maintenance (NEm) of beef cows was obtained by the following equation:

$$HP = 97.8 \times \exp^{(0.0024 \times MEI)}, S_{XY} = 0.5578$$

where HP = heat production expressed as kcal/EBW$^{0.75}$/d and MEI = metabolizable energy intake (kcal/EBW$^{0.75}$/d). Thus, from the previous equation, when MEI is equivalent to zero, we can obtain the value of 97.8 kcal/EBW$^{0.75}$/d, that is the net energy required for the maintenance of lactating Zebu cows.

The NRC (1996) stablished the NEm for beef cattle as 77 kcal/EBW$^{0.75}$/d, obtained from the data of Lofgreen and Garret (1968). Also, this system recommended discounts of 10% for Zebu cattle and an increase of 20% for lactating beef cows. Therefore, adopting these recommendations, the net energy required for the maintenance of lactating Zebu cows, according to the NRC (1996), would be 83.2 kcal/EBW$^{0.75}$/d. Buskirk et al. (1992) estimated the NEm to be 72.5 kcal/SBW$^{0.75}$/d for Angus cows.

Utilizing the recommendations of the last edition of the BR-CORTE, in 2010, the NEm for Zebu cattle of different sexes was estimated as 74.2 kcal/EBW$^{0.75}$/d. Considering the increase of 20% for lactating cows (NRC, 1996), the value obtained for this animal category should be 89.0 kcal/EBW$^{0.75}$/d, which is below the result obtained by Fonseca (2009), of 97.8 kcal/EBW$^{0.75}$/d.

Therefore, due to the lack of information for this animal category, BR-CORTE (2016) recommended the use of the value of 97.8 kcal/EBW$^{0.75}$/d as the net energy required for the maintenance of lactating Nellore cows.

The metabolizable energy required for the maintenance (MEm) of lactating Zebu cows was obtained when the MEI was equal to heat production using the iterative process in the previously proposed equation, which resulted in the MEm of 135.4 kcal/EBW$^{0.75}$/d. From these values, the efficiency of the use of metabolizable energy (ME) for maintenance (*km*) was estimated as 72% (97.8/135.4). In a study developed by Freetly et al. (2006) using lactating primiparous beef cows (Hereford × Angus × Red Polled × Pinzgauer), the MEm was estimated as 146 kcal/BW$^{0.75}$/d and the efficiency of the use of ME for maintenance was 72%. Nevertheless, Calegare et al. (2007) estimated the MEm as 141.3 kcal/BW$^{0.75}$/d for lactating Nellore cows, being this value close to that observed by Fonseca (2009).

The energy loss related to body reserve mobilization was obtained from the body composition of cows slaughtered after calving as baseline and those fed at maintenance level during the first 90 days of lactation who lost body weight. Then, the negative retained energy was 2.1 Mcal/d divided by body weight losses of 0.48 kg/d, resulting in the mean value of 4.3 Mcal/BW loss. This value is below those recommended by other nutrient requirement systems that utilized *Bos taurus* cattle as a baseline for the calculations which could explain the differences between them (Table 11.5). The efficiency of the use of energy from body reserve mobilization for MY obtained by Freetly et al. (2006) was 78%, while the AFRC (1993) and the CSIRO (2007) considered this efficiency as 84%.

Table 11.5 - Energy loss related to body weight mobilization (Mcal/kg BW loss) according to different nutrient requirement systems

Characteristic	Fonseca (2009)	NRC (1996)	CSIRO (2007)		INRA (1989)	AFRC (1993)
			British breeds	European breeds		
Body reserve mobilization	4.3	5.8	6.4	5.5	6.0	4.5

However, few studies involving the estimate of nutrient requirements of Zebu female cattle were conducted in Brazil (Calegare et al., 2007; Fonseca, 2009; Marcondes et al., 2009; Costa e Silva et al., 2015b). Also, these studies were conducted in feedlot, where the animals were housed in individual pens to allow increased control for important variables such as metabolizable energy intake to be obtained, which is utilized for calculations of the estimates.

Thereby, we believe that there is an underestimation of the energy obtained for the maintenance of animals maintained in feedlot, because it is not considered an extra energy expense that would be observed for animals raised on pasture. In an extensive situation, the heat production of animals is influenced by several interrelated factors such as forage availability and quality, environment conditions, and animal behavior when raised on pasture, as described in the chapter about energy requirements for beef cattle.

According to studies conducted with animals raised on pasture where heat production was estimated from heart beats rate, energy expenditure related to activities of grazing and locomotion, both horizontal and vertical plans in pasture areas, corresponded to 8 and 11.2% of total energy production, respectively (Brosh et al., 2010). Thus, researches evaluating the increase in requirements for maintenance that grazing activities can cause in the breast-feeding herd might be conducted in Brazil to improve the understanding of variations on energy efficiency of the animals (Kelly et al., 2010).

The net energy required for growth (NEg) of lactating Nellore cows were calculated from equation described by Fonseca (2009):

$$NEg = EBG \times (1.0076 \times EBW^{0.2389}),$$

where NEg = net energy required for growth (Mcal/d), EBG = empty body gain (kg/d), and EBW = empty body weight (kg). The efficiency of the use of metabolizable energy (ME) for growth (*kg*) of lactating Nellore cows was 0.44, equivalent to the slope of the equation from relationship between RE (kcal/EBW$^{0.75}$/d) and MEI (kcal/EBW$^{0.75}$/d) described in Figure 11.3. Flatt et al. (1967), evaluating lactating Holstein cows, found the value of 0.64 for *kg*. If a retained energy equal to zero is considered, the requirements of ME for maintenance of beef lactating cows would be estimated as 140.1 kcal/EBW$^{0.75}$/d, which is a value close to that obtained by the iterative process (Figure 11.3).

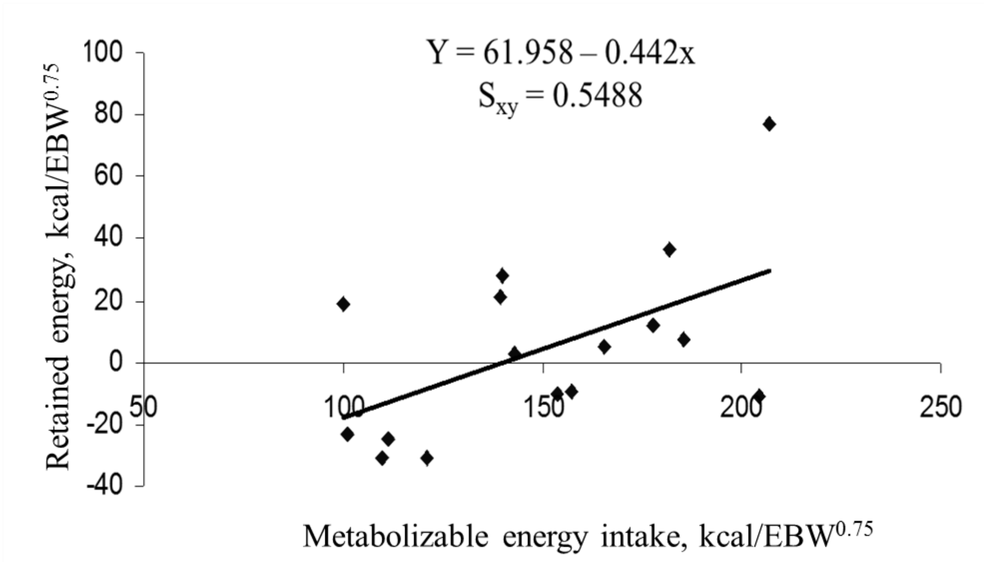

Figure 11.3 - Retained energy as a function of metabolizable energy intake. Adapted from Fonseca et al. (2012).

The net energy required for lactation (NE_l) was considered as the net energy from milk, which resulted in 0.75 Mcal/kg milk in the study of Fonseca (2009). Considering the efficiency of the use of metabolizable energy for lactation (k_l) equal to *km* (BCNRM, 2016) of 0.72, the requirements of ME for lactation (ME_l) are 1.04 Mcal/kg milk.

In addition, the NE per kg of milk can be obtained from milk constituents, with each component multiplied by its respective energy value. Thus, using the average milk composition from Costa e Silva et al. (2015a) of 3.69% CP, 4.59% lactose, and 5.61% fat, the requirement of NE for lactation, using the equation proposed by NRC (2001): NE_l (Mcal/kg milk) = 0.0929 × % fat + 0.0547 × % protein + 0.0395 × % lactose, is 0.904 Mcal/kg milk. Moreover, ME_l can be calculated as 1.26 Mcal/kg milk (0.904/0.72), which is higher than that found by Fonseca (2009), possibly due to the greater fat content in the milk found by Costa e Silva et al. (2015a). Alternatively, if there is no complete milk composition, or when there is only knowledge of the fat content of milk, the equation from NRC (2001) can be used: NE_l (Mcal/kg milk) = 0.36 + 0.0969 × % fat.

To convert ME to TDN was considered, first to convert ME to DE (for more details, see Chapter 6): ME = 0.9455 × DE – 0.3032, and then to convert from DE to TDN, the factor of 4.4 was utilized. Thereby, the NE_l would result in TDN requirements of 0.38 kg/kg milk when ME_l is 1.26 Mcal/kg milk.

ENERGY REQUIREMENTS FOR SUCKLING BEEF CALVES

The conversion of SBW for empty body weight (EBW) of suckling calves can be obtained by the ratio EBW/SBW, which is equal to 0.962. Also, ADG can be converted to empty body gain (EBG) by the ratio EBG/ADG equal to 0.958 for suckling calves (Fonseca et al., 2012b). Due to the lack of adjustment of data from the study of Fonseca et al. (2012b), the requirements of ME for the maintenance of suckling calves was not estimated in the last edition of the BR-CORTE; however, Costa e Silva et al. (2015b) evaluated the requirements of NEm of Nellore calves with body weight varying from 121 to 300 kg and suggested the following equation:

$$HP = 0.294 \times \exp^{(1.0530 \times MEI)}$$

where HP = heat production is given as $MJ/EBW^{0.75}/d$ and MEI = metabolizable energy intake ($MJ/EBW^{0.75}/d$).

Thus, from the previous equation, the NEm can be obtained as 294 $kJ/EBW^{0.75}/d$, or 70.3 $kcal/EBW^{0.75}/d$ for Nellore calves. For the requirements of ME for maintenance, when MEI is equal to heat produced at fasting, using the same equation, the value obtained was 118.6 $kcal/EBW^{0.75}/d$. Therefore, dividing NEm by MEm, the efficiency of the use of metabolizable energy for maintenance was 59.3%. The net energy required for growth (NEg) of suckling Nellore calves (Fonseca et al., 2012b) was estimated using the following equation:

$$NEg = 0.0932 \times EBW^{0.75} \times EBG^{0.9157}$$

where NEg = net energy required for growth (Mcal/d), $EBW^{0.75}$ = metabolic empty body weight, and EBG = empty body gain.

To convert the net energy required for growth (NEg) to the metabolizable energy required for growth (MEg), two factors of efficiency of the use of MEg were utilized, with *kg* = 0.69 for milk intake and *kg* = 0.57 for solid feedstuffs intake according to the recommendations of the NRC (2001). Then, in the period from 0 to 90 days of age, the *kg* of 0.66 was considered (77 × 0.69 + 23 × 0.57) corresponding to the body weight of the animals weighing up to 100 kg; in the period from 90 to 180 days (> 100 kg body weight), the *kg* of 0.62 was considered (43 × 0.69 + 57 × 0.57), with 77 and 23%, and 43 and 57% being the relationships between milk intake and solid feedstuffs consumed by calves in the respective periods (Fonseca, 2009).

The DE requirements were calculated as ME/0.96 (NRC, 2001; for suckling calves) and the TDN requirements were calculated as: DE/4.4.

PROTEIN REQUIREMENTS FOR LACTATING BEEF COWS

The requirements of metabolizable protein for maintenance (MPm) were calculated from the equation suggested by this edition of the BR-CORTE (for more details, see Chapter 8) for animals raised on pasture:

$$MPm = 3.9 \times SBW^{0.75}$$

where $SBW^{0.75}$ = metabolic shrunk body weight. The net requirements of protein for growth (NPg) of primiparous Nellore cows were calculated from the equation proposed by Fonseca (2009):

NPg (g/d) = EBG × (376.4 × $EBW^{-0.1839}$).

To convert the NPg for the requirements of metabolizable protein for growth (MPg), the efficiency (*k*) was obtained using the recommendation suggested by the BR-CORTE (2016):

k = 47.4%.

The protein required for lactation is based on the amount of protein secreted in the milk. From the equation presented to estimate milk yield, the amount of protein produced in the milk can be estimated. The NRC (2001) suggests an equation to calculate the requirements of metabolizable protein for lactation (MP_l):

MP_l (g/d) = CPmilk/0.67 × 1000

where CPmilk = true protein presented in the milk (kg/d), and 0.67 = efficiency of the use of metabolizable protein for lactation.

The average of CP content in the milk of Zebu cows obtained by Costa e Silva et al. (2015a) was 3.69%; this CP content was multiplied by the percentage of true protein in milk (AFRC, 1993), which is 95%, resulting in the value of 3.50% or 35.0 g of true protein per kilogram of milk. Schroeder and Titgemeyer (2008) performed a review regarding the efficiency of the use of MP and said that the efficiencies of the use of digestible protein for body protein growth observed in calves were lower than the fixed value of 67% adopted by the NRC (2001).

Furthermore, this efficiency can be affected by several factors, such as the level of protein and energy intake, BW, age, genotype of the animals, and feeding frequency (Schroeder and Titgemeyer, 2008). Due to the lack of a consistent value, we considered the efficiency of the use of metabolizable protein for lactation to be 0.67 (NRC, 2001), which resulted in the value of 52.3 g metabolizable protein (MP) per kilogram of milk, corresponding to the requirements of MP for lactation. This value is greater than 44.8 g MP per kilogram of milk presented for a milk with 3.15% CP (AFRC, 1993; NRC, 2001). Therefore, we recommend that the requirements of MP for lactating beef cows might be 52.3 g/kg milk.

The microbial crude protein synthesis (MCP) was calculated considering the recommendation presented in the Chapter 3, where microbial CP synthesis was calculated as a function of the intakes of crude protein (CPI) and total digestible nutrients (TDNI) as follows:

MCP (g/d) = -53.07 + 304.9 × CPI + 90.8 × TDNI – 3.13 × $TDNI^2$,

where CPI = crude protein intake (kg/d) and TDNI = total digestible nutrients intake (kg/d). Thus, the requirements of rumen degradable protein (RDP) were calculated from the recommendations of this edition, where microbial protein synthesis equals RDP requirements (for more details, see Chapter 8):

RDP = MCP,

where the requirements of rumen undegradable protein (RUP) were obtained from the following equation:

RUP = (Total metabolizable protein – (MCP × 0.64))/0.80.

So, the requirements of crude protein would be equal to the sum of RDP and RUP.

PROTEIN REQUIREMENTS FOR SUCKLING BEEF CALVES

The recommendations for the requirements of metabolizable protein for maintenance (MPm) were based on the equation suggested in this edition of the BR-CORTE for animals raised on pasture (for more details, see Chapter 8):

MPm = 3.9 × $SBW^{0.75}$.

The net requirements of protein for the growth of suckling beef calves were calculated from the equation developed by Fonseca (2009):

NPg (g/d) = EBG × (139.7 × $EBW^{0.0351}$).

To convert the NPm for the requirements of metabolizable protein for growth (MPg), the efficiency (*k*) was calculated using the equation described by the BR-CORTE (2010):

$k = 84.665 - 0.1179 \times EQEBW$.

The same way as for cows, the microbial crude protein synthesis (MCP) was calculated considering the recommendation presented in the Chapter 3, in which microbial synthesis was calculated as a function of the intakes of crude protein (CPI) and total digestible nutrients (TDNI).

However, calves, when consuming milk, present reflex for the formation of an esophageal groove, causing milk to go directly into the abomasum without suffering the action of microorganisms in the rumen. In this case, considering that protein and energy from milk to get MCP would not be the most correct. Thus, for suckling calves, we recommend that the intakes of CP and TDN from milk should be removed from the calculation of MCP, because, otherwise, there will be an overestimation of RDP and an underestimation of RUP. Therefore, to calculate MCP of suckling calves, we recommend the use of the following equation:

$$MCP (g/d) = -53.07 + 304.9 \times (total\ CPI - CPImilk) + 90.8 \times (total\ TDNI - TDNImilk) - 3.13 \times (total\ TDNI - TDNImilk)^2,$$

where total CPI = total crude protein intake in the diet (kg/d), CPImilk = crude protein intake from milk (kg/d), total TDNI = total digestible nutrients intake in the diet (kg/d), and TDNImilk = total digestible nutrients intake from milk (kg/d).

For calculation of CPImilk, the milk yield of cows might be quantified and multiplied by the crude protein content of the milk. For TDN, initially, the contents of protein, lactose and fat in the milk might be quantified. According to the publication of Maynard et al. (1979), which states that the digestibility of milk constituents is 0.98 (carbohydrates), 0.95 (fat) and from BCNRM (2016) of 0.95 (protein), we considered the sum of the digestible constituents of the milk to account for the TDN intake from milk as shown in the following equation:

$$TDNImilk = MY \times ((\%\ CP \times 0.95 + \%\ lactose \times 0.98) + (2.25 \times \%\ fat \times 0.95)).$$

Considering the mean milk composition from the study of Costa e Silva et al. (2015a) as 3.69% CP, 4.59% lactose, and 5.61% fat, the TDN content of this milk would be approximately 20% on a natural basis or 138% on a dry matter basis of the milk (20/0.145).

However, considering that calves with a BW lower than 100 kg presenting low microbial activity in the rumen due to the intake almost exclusively from milk, and data for this animal category beyond this point being scarce for this body weight range, this edition of the BR-CORTE adopted the same recommendation as the last edition of the BR-CORTE in 2010 to estimate microbial protein synthesis (MCP) of 120 g MCP/kg TDN. However, we highlight the need to discount TDN from milk; otherwise, the estimate of MCP would be overestimated.

Additionally, the requirements of rumen degradable protein (RDP) were calculated from the recommendation of this edition of the BR-CORTE, for which microbial protein synthesis is equal to the RDP requirements (for more details, see Chapter 8):

$$RDP = MCP,$$

where the requirements of rumen undegradable protein (RUP) were obtained from the following equation:

$$RUP = (total\ metabolizable\ protein - (MCP \times 0.64))/0.80.$$

To obtain the crude protein requirements, the sum of the requirements of RDP and RUP should be considered.

MINERAL REQUIREMENTS FOR LACTATING BEEF COWS AND THEIR CALVES

Due to the lack of data related to mineral requirements for the maintenance and retention coefficient of lactating beef cows and suckling calves, these estimates were calculated according to recommendations presented in Chapter 9 about the mineral requirements for beef cattle. With regard to the net requirements of macrominerals (Ca, P, Mg, Na, and K) for growth, the amounts of each mineral present in the animal's body were regressed as a function of EBW from the following model:

$$Mi = a \times EBW^{b},$$

where Mi = the amount of each macromineral (Ca, P, Mg, Na, and K; g) present in the animal body and EBW = empty body weight (kg).

From the derivative of the equation above, the net requirements of macrominerals (Ca, P, Mg, Na, and K) for the growth of lactating beef cows and suckling calves were calculated from the following model:

$$Y = a \times b \times EBW^{b-1},$$

which Y = net requirements of each mineral for growth (g/d), EBW = empty body weight (kg).

Thus, the equations generated to estimate the net requirements of each mineral for growth considering each animal category are shown in the Table 11.6. Due to non-adjustment to data for Ca of lactating cows (Fonseca, 2009), the recommendation from Chapter 9 was used to estimate the net requirements for the growth of this mineral. Furthermore, due to the lack of recommendations for sulfur and microminerals for both animal categories (Fonseca, 2009), the equations described in the Chapter 9 were adopted.

Table 11.6 - Net requirements of macrominerals (Ca, P, Mg, Na, and K) for growth of lactating beef cows and their calves

Item	Equations	
	Cows[1]	Calves
Ca	EBW < 462 kg: $EBG \times (147 \times EBW^{-0.50})$ EBW ≥ 462 kg: NRCa (kg) = 0	$EBG \times (54.8 \times EBW^{-0.3981})$
P	$EBG \times (54.4 \times EBW^{-0.4484})$	$EBG \times (8.6 \times EBW^{-0.0371})$
Mg	$EBG \times (1.4 \times EBW^{-0.3227})$	$EBG \times (0.4 \times EBW^{-0.0173})$
Na	$EBG \times (1.4 \times EBW^{-0.0575})$	$EBG \times (1.2 \times EBW^{-0.0209})$
K	$EBG \times (3.1 \times EBW^{-0.2142})$	$EBG \times (1.5 \times EBW^{-0.0636})$

[1]Recomendation for calcium from Chapter 9. Other equations adapted from Fonseca (2009). EBW = empty body weight (kg); EBG = empty body gain (kg/d). Considering cows heavier than 544 kg BW, the net Ca required for growth is equal to zero (for more details, see Chapter 9).

TABLES OF THE NUTRIENT REQUIREMENTS OF LACTATING BEEF COWS AND THEIR CALVES

From estimates of the requirements of energy, protein, and macrominerals for growth of lactating beef cows and suckling calves, dietary requirements of the nutrients can be calculated. The equations utilized for the calculations of the nutrient requirements of lactating beef cows and suckling calves are shown in the Tables 11.7, 11.8, and 11.9, respectively, with the equation utilized to calculate microbial N described in Chapter 3, while the net requirements of macrominerals for maintenance, true retention coefficient, and dietary requirements of microminerals are described in Chapter 9.

Table 11.7 - Summary of the equations to estimate energy and protein requirements for lactating beef cows and their calves

Item	Equations		Unit
	Cows	Calves	
DMI	$((27.259 - 13.861 \times \exp^{(-0.836 \times W)} - 0.317 \times W + 0.606 \times ADG) \times BW)/1000$	$0.353 - 0.532 \times DMImilk + 0.01065 \times BW + 0.3497 \times ADG$	kg/d
MY	$8.819 - 0.069 \times W - 8.819 \times \exp^{(-3.211 \times W)}$	-	kg/d
SBW	$0.88 \times BW^{1.0175}$	-	kg
EBW	$0.8507 \times SBW^{1.0002}$	$0.962 \times SBW$	kg
EBG	$0.936 \times ADG$	$0.958 \times ADG$	kg/d
NEm	$97.8 \times EBW^{0.75}$	$70.3 \times EBW^{0.75}$	kcal/d
MEm	$135.0 \times EBW^{0.75}$	$118.6 \times EBW^{0.75}$	kcal/d
km	NEm/MEm		%
NEg	$EBG \times (1.0076 \times EBW^{0.2389})$	$0.0932 \times EBW^{0.75} \times EBG^{0.9157}$	Mcal/d
kg	44	Milk = 69 Solids = 57	%
MEg	NEg/kg		Mcal/d
NE_l	0.75	-	Mcal/kg milk
k_l	*km*	-	%
ME_l	NE_l / k_l		Mcal/d
MEt	$MEm + MEg + ME_l$	MEm + MEg	Mcal/d
DE	$(((MEt/DMI) + 0.3032)/0.9455) \times DMI$	MEt/0.96	Mcal/d
TDN	DE / 4.4		kg/d
MPm	$3.9 \times SBW^{0.75}$		g/d
NPg	$EBG \times (376.4 \times EBW^{-0.1839})$	$EBG \times (139.7 \times EBW^{0.0351})$	g/d
k	47.4	$84.665 – 0.1179 \times EQEBW$	%
MP_l	52.3	-	g/kg milk
MPt	$MPm + MPg + MP_l$	MPm + MPg	g/d
CPImilk	-	$MY \times 0.0369$	g/d
TDNImilk	-	$MY \times 0.20$	kg/d
MCP	$-53.07 + 304.9 \times CPI + 90.8 \times TDNI – 3.13 \times TDNI^2$	SBW < 150 kg: 120 g/kg TDN SBW > 150 kg: $-53.07 + 304.9 \times (CPI – CPImilk) + 90.8 \times (TDNI – TDNImilk) – 3.13 \times (TDNI – TDNImilk)^2$	g/d
RDP	MCP		g/d
RUP	$(MPt - (MCP \times 0.64))/0.80$		g/d
CP	RDP + RUP		g/d

Table 11.8 - Summary of the equations to estimate the net requirements of macrominerals (Ca, P, Mg, Na, K, and S) for growth (g/d) of lactating beef cows and their calves

Item	Equations	
	Cows	Calves
Ca	EBW < 462 kg: EBG × (147 × $EBW^{-0.50}$) EBW ≥ 462 kg: NRCa (kg) = 0	EBG × (54.8 × $EBW^{-0.3981}$)
P	EBG × (54.4 × $EBW^{-0.4484}$)	EBG × (8.6 × $EBW^{-0.0371}$)
Mg	EBG × (1.4 × $EBW^{-0.3227}$)	EBG × (0.4 × $EBW^{-0.0173}$)
Na	EBG × (1.4 × $EBW^{-0.0575}$)	EBG × (1.2 × $EBW^{-0.0209}$)
K	EBG × (3.1 × $EBW^{-0.2142}$)	EBG × (1.5 × $EBW^{-0.0636}$)
S	EBG × (0.03 × $EBW^{0.8900}$)	

[1]EBW = empty body weight (kg); EBG = empty body gain (kg/d). Considering cows heavier than 544 kg BW, the net Ca required for growth is equal to zero (for more details, see Chapter 9).

Table 11.9 - Summary of the equations utilized for the calculation of dietary requirements of microminerals (Cu, Co, Cr, Fe, Mn, Mo, Se, and Zn) for beef cattle (Adapted from Chapter 9)

Mineral	Net requirements for maintenance	Retention coefficient	Net requirements for growth (NRG)[1]
	μg/kg body weight	%	mg/d
Cu	95.6	73.5	NRG_{Cu} = EBG × (1.25 × $EBW^{0.33}$)
Co	13.5	86.8	NRG_{Co} = EBG × (0.045 × $EBW^{-0.023}$)
Cr	22.9	78.4	NRG_{Cr} = EBG × (0.23 × $EBW^{0.61}$)
Fe	2,942	73.4	NRG_{Fe} = EBG × (14.0 × $EBW^{0.24}$)
Mn	184.9	43.9	NRG_{Mn} = EBG × (0.07 × $EBW^{0.80}$)
Mo	3.27	49.7	NRG_{Mo} = EBG × (0.0035 × $EBW^{0.41}$)
Se	3.72	48.7	NRG_{Se} = EBG × (1.07 × $EBW^{-0.07}$)
Zn	334.4	66.8	NRG_{Zn} = EBG × (1.16 × $EBW^{0.86}$)

[1]EBG = empty body gain (kg/d); EBW = empty body weight (kg).

Thereby, considering a 450-kg lactating beef cows in the 10th week of lactation with average daily gain of 0.2 kg/d, we have:

• DMI = 27.259 – 13.861 × $\exp^{(-0.836 \times 10)}$ – 0.317 × 10 + 0.606 × 0.20 = 24.21 g/kg BW
• DMI = (24.21 g/kg BW × 450 kg)/1000 = 10.89 kg/d
• MY = 8.819 – 0.069 × W – 8.819 × $\exp^{(-3.211 \times W)}$ = 8.819 – 0.069 × 10 – 8.819 × $\exp^{(-3.211 \times 10)}$ = 8.13 kg/d
• SBW = 0.88 × $BW^{1.0175}$ = 0.88 × $450^{1.0175}$ = 441 kg
• EBW = 0.8507 × $SBW^{1.0002}$ = 0.8507 × $441^{1.0002}$ = 375.3 kg
• EBG = 0.936 × ADG = 0.936 × 0.2 = 0.187 kg/d

- **Energy requirements** (Table 11.10):

• NEm = 97.8 × $EBW^{0.75}$ = 97.8 × $375.3^{0.75}$ = 8,344 kcal/d = 8.34 Mcal/d
• MEm = 135.0 × $EBW^{0.75}$ = 135.0 × $375.3^{0.75}$ = 11,511 kcal/d = 11.5 Mcal/d
• NEg = 1.0076 × $EBW^{0.2389}$ × EBG = 1.0076 × $375.3^{0.2389}$ × 0.187 = 0.78 Mcal/d
• MEg = NEg/kg = 0.78/0.44 = 1.77 Mcal/d
• NE_l = 0.75 Mcal/kg milk = 0.75 × 8.13 = 6.10 Mcal/d
• ME_l = NE_l/k_l = 6.10/0.72 = 8.47 Mcal/d
• MEt = MEm + MEg + ME_l = 11.5 + 1.77 + 8.47 = 21.74 Mcal/d
• DE =(((MEt/DMI) + 0.3032)/0.9455) × DMI = (((21.74/10.89) + 0.3032)/0.9455) × 10.89 = 26.48 Mcal/d
• TDN = DE/4.4 = 26.48/4.4 = 6.02 kg/d

- Protein requirements (Table 11.10):
• $MPm = 3.9 \times SBW^{0.75} = 3.9 \times 441^{0.75} = 375.1$ g/d
• $NPg = 0.3764 \times EBW^{-0.1839} \times EBG = 0.3764 \times 375.3^{-0.1839} \times 0.187 = 0.0237$ kg/d = 23.70 g/d
• $MPg = NPg/k = 23.70/0.474 = 50.0$ g/d
• $MP_l = 52.3$ g/kg milk = 52.3 × 8.13 = 425.2 g/d
• $MPt = MPm + MPg + MP_l = 375.1 + 50.0 + 425.2 = 850.3$ g/d
• $MCP = -53.07 + 304.9 \times CPI + 90.8 \times TDNI - 3.13 \times TDNI^2 = -53.07 + 304.9 \times 1.213 + 90.8 \times 6.02 - 3.13 \times (6.02)^2 = 750$ g/d
• RDP = MCP = 750 g/d
• RUP = (MPt – (MCP × 0.64))/0.80 = (850.3 – (750 × 0.64))/0.80 = 462.9 g/d
• CP = RDP + RUP = 750 + 462.9 = 1,213 g/d

To obtain the concentration required of TDN and CP (% DM in the diet), the requirements of TDN (6.02 kg/d) and CP (1212.9 g/d) might be divided by the DMI of the animal.
• TDN (% DM in the diet) = TDN/DMI = 6.02/10.89 = 55.28%
• CP (% DM in the diet) = CP/DMI = 1.213/10.89 = 11.13%

- **Mineral requirements** (Table 11.10):
• Calcium:
- Net requirements for maintenance = 11.7 × 450/1,000 = 5.27 g/d
- Net requirements for growth = $EBG \times (147 \times EBW^{-0.50}) = 0.187 \times (147 \times 375.3^{-0.50}) = 1.42$ g/d
- Net requirements for lactation = 1.1 g/kg milk = 1.1 × 8.13 = 8.94 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (5.27 + 1.42 + 8.94)/0.568 = 27.52 g/d

• Phosphorus:
- Net requirements for maintenance = 13.5 × 450/1,000 = 6.08 g/d
- Net requirements for growth = $EBG \times (54.4 \times EBW^{-0.4484}) = 0.187 \times (54.4 \times 375.3^{-0.4484}) = 0.71$ g/d
- Net requirements for lactation = 0.77 g/kg milk = 0.77 × 8.13 = 6.26 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (6.08 + 0.71 + 6.26)/0.678 = 19.25 g/d
Ca:P ratio = 27.52/19.25 = 1.43

• Magnesium:
- Net requirements for maintenance = 5.9 × 450/1,000 = 2.66 g/d
- Net requirements for growth = $EBG \times (1.4 \times EBW^{-0.3227}) = 0.187 \times (1.4 \times 375.3^{-0.3227}) = 0.039$ g/d
- Net requirements for lactation = 0.07 g/kg milk = 0.07 × 8.13 = 0.57 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (2.66 + 0.039 + 0.57)/0.355 = 9.21 g/d

• Sodium:
- Net requirements for maintenance = 6.3 × 450/1,000 = 2.84 g/d
- Net requirements for growth = $EBG \times (1.4 \times EBW^{-0.0575}) = 0.187 \times (1.4 \times 375.3^{-0.0575}) = 0.186$ g/d
- Net requirements for lactation = 0.2 g/kg milk = 0.2 × 8.13 = 1.63 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (2.84 + 0.186 + 1.63)/0.371 = 12.55 g/d

• Potassium:
- Net requirements for maintenance = 23.5 × 450/1,000 = 10.58 g/d
- Net requirements for growth = $EBG \times (3.1 \times EBW^{-0.2142}) = 0.187 \times (3.1 \times 375.3^{-0.2142}) = 0.163$ g/d
- Net requirements for lactation = 0.7 g/kg milk = 0.7 × 8.13 = 5.69 g/d

- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (10.58 + 0.163 + 5.69)/0.484 = 33.95 g/d

• Sulfur:
- Net requirements for maintenance = 10.4 × 450/1,000 = 4.68 g/d
- Net requirements for growth = EBG × (0.03 × $EBW^{0.89}$) = 0.187 × (0.03 × $375.3^{0.89}$) = 1.10 g/d
- Net requirements for lactation = 0.3 g/kg milk = 0.3 × 8.13 = 2.44 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (4.68 + 1.10 + 2.44)/0.773 = 10.63 g/d

• Cobalt:
- Net requirements for maintenance = 13.5 × 450/1,000 = 6.08 mg/d
- Net requirements for growth = EBG × (0.045 × $EBW^{-0.023}$) = 0.187 × (0.045 × $375.3^{-0.023}$) = 0.007 mg/d
- Net requirements for lactation = 2.3 mg/kg milk = 2.3 × 8.13 = 18.70 mg/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (6.08 + 0.007 + 18.70)/0.868 = 28.56 mg/d

• Copper:
- Net requirements for maintenance = 95.6 × 450/1,000 = 43.02 mg/d
- Net requirements for growth = EBG × (1.25 × $EBW^{0.33}$) = 0.187 × (1.25 × $375.3^{0.33}$) = 1.65 g/d
- Net requirements for lactation = 1.99 mg/kg milk = 1.99 × 8.13 = 16.18 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (43.02 + 1.65 + 16.18)/0.735 = 82.79 mg/d

• Chromium:
- Net requirements for maintenance = 22.9 × 450/1,000 = 10.31 mg/d
- Net requirements for growth = EBG × (0.23 × $EBW^{0.61}$) = 0.187 × (0.23 × $375.3^{0.61}$) = 1.60 mg/d
- Net requirements for lactation = 3.2 mg/kg milk = 3.2 × 8.13 = 26.0 g/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (10.31 + 1.60 + 26.0)/0.784 = 48.35 g/d

• Iron:
- Net requirements for maintenance = 2,942 × 450/1,000 = 1,324 mg/d
- Net requirements for growth = EBG × (14.0 × $EBW^{0.24}$) = 0.187 × (14.0 × $375.3^{0.24}$) = 10.86 mg/d
- Net requirements for lactation = 29.9 mg/kg milk = 29.9 × 8.13 = 243.1 mg/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (1,324 + 10.86+ 243.1)/0.734 = 2,150 mg/d

• Manganese:
- Net requirements for maintenance = 184.9 × 450/1,000 = 83.21 mg/d
- Net requirements for growth = EBG × (0.07 × $EBW^{0.80}$) = 0.187 × (0.07 × $375.3^{0.80}$) = 1.50 mg/d
- Net requirements for lactation = 1.41 mg/kg milk = 1.41 × 8.13 = 11.46 mg/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (83.21 + 1.50 + 11.46)/0.439 = 219.1 mg/d

• Zinc:
- Net requirements for maintenance = 334.4 × 450/1,000 = 150.5 mg/d
- Net requirements for growth = EBG × (1.16 × $EBW^{0.86}$) = 0.187 × (1.16 × $375.3^{0.86}$) = 35.50 mg/d
- Net requirements for lactation = 35.4 mg/kg milk = 35.4 × 8.13 = 287.8 mg/d
- Dietary requirements = (Net requirements for maintenance + growth + lactation)/retention coefficient = (150.5 + 35.50 + 287.8)/0.668 = 709 mg/d

Table 11.10 – Energy, protein, macrominerals and microminerals requirements for lactating beef cows

Requirements	Body weight (kg)								
	400			450			500		
ADG (kg/d)	0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30
DMI (kg/d)	9.66	9.68	9.71	10.87	10.89	10.92	12.07	12.10	12.13
Energy (Mcal/d)									
NEm		7.62			8.34			9.04	
MEm		10.5			11.5			12.5	
NEg	0.38	0.76	1.13	0.39	0.78	1.17	0.40	0.80	1.20
MEg	0.86	1.72	2.58	0.88	1.77	2.65	0.91	1.81	2.72
NE_l		6.10			6.10			6.10	
ME_l		8.47			8.47			8.47	
MEt	19.8	20.7	21.6	20.9	21.7	22.6	21.9	22.8	23.7
TDN (kg/d)	5.48	5.68	5.89	5.81	6.02	6.24	6.13	6.35	6.57
Crude protein (g/d)									
MPm		343			375			407	
NPg	12.1	24.2	36.3	11.8	23.7	35.5	11.6	23.2	34.8
MPg	25.5	51.1	76.6	25.0	50.0	75.0	24.5	49.0	73.5
MPl		425			425			425	
MPt	794	819	845	825	850	875	856	881	905
RDP	695	718	740	727	750	772	759	781	802
RUP	436	450	464	450	463	477	463	476	490
CP	1,131	1,168	1,204	1,177	1,213	1,248	1,222	1,257	1,292
Macrominerals (g/d)									
Ca	25.3	26.6	28.0	26.3	27.5	28.8	27.2	28.4	29.6
P	17.8	18.3	18.9	18.7	19.2	19.8	19.7	20.2	20.7
Mg	8.31	8.36	8.42	9.14	9.19	9.25	9.97	10.0	10.1
Na	11.4	11.7	11.9	12.3	12.5	12.8	13.1	13.4	13.6
K	31.4	31.5	31.7	33.8	33.9	34.1	36.2	36.4	36.5
S	9.18	9.81	10.5	9.92	10.6	11.3	10.7	11.4	12.2
Microminerals (mg/d)									
Co	27.8	27.8	27.8	28.5	28.5	28.6	29.3	29.3	29.3
Cu	75.1	76.2	77.3	81.7	82.8	83.9	88.2	89.4	90.5
Cr	45.8	46.8	47.7	47.3	48.4	49.4	48.9	50.0	51.1
Fe	1,942	1,949	1,956	2,142	2,150	2,157	2,343	2,350	2,358
Mn	196	198	199	217	219	221	239	240	242
Zn	655	679	703	683	709	736	710	739	769

*Considering a cow in the 10th week of lactation and milk yield of 8.13kg/d.

To exemplify the nutrient requirements of suckling beef calves, a 150-kg calf (BW = SBW), son of the cow utilized in the previous example, was considered with ADG of 0.80 kg/d and consuming a diet consisted by 55% milk and 45% forage + concentrate on DM basis:

• DMImilk = MY × % DM milk = 8.13 × 0.145 = 1.18 kg/d
• DMIrc = 0.353 - 0.532 × DMImilk + 0.01065 × BW + 0.34965 × ADG = 0.353 – 0.532 × 1.18 + 0.01065 × 150 + 0.3497 × 0.80 = 1.60 kg/d
• $DMI_{total} = DMI_{rc} + DMI_{milk}$ = 1.60 + 1.18 = 2.78 kg/d
• EBW = 0.962 × SBW = 0.962 × 150 = 144 kg
• EBG = 0.958 × ADG = 0.958 × 0.80 = 0.77 kg/d

- **Energy requirements** (Table 11.11):
• NEm = 70.3 × $EBW^{0.75}$ = 70.3 × $144^{0.75}$ = 2.93 Mcal/d
• MEm = 118.6 × $EBW^{0.75}$ = 118.6 × $144^{0.75}$ = 4.94 Mcal/d
• NEg = 0.0932 × $EBW^{0.75}$ × $EBG^{0.9157}$ = 0.0932 × $144^{0.75}$ × $0.77^{0.9157}$ = 3.04 Mcal/d
• kg = 55 × 0.69 + 45 × 0.57 = 0.64
• MEg = NEg/kg = 3.04/0.64 = 4.75 Mcal/d
• MEt = MEm + MEg = 4.94 + 4.75 = 9.69 Mcal/d
• DE = ME/0.96 = 9.69/0.96 = 10.1 Mcal/d
• TDN = DE/4.4 = 10.1/4.4 = 2.29 kg/d

- **Protein requirements** (Table 11.11):
• MPm = 3.9 × $SBW^{0.75}$ = 3.9 × $150^{0.75}$ = 167 g/d
• NPg = 0.1397 × $EBW^{0.0351}$ × EBG = 0.1397 × $144^{0.0351}$ × 0.77 = 0.1275 kg/d= 127.5 g/d
• k = 84.665 – 0.1179 × EQEBW = 84.665 – 0.1179 × 144 = 67.7%
• MPg = NPg/k = 127.5/0.677 = 188.4 g/d
• MPt = MPm + MPg = 167 + 188.4 = 356.4 g/d
• CPImilk = MY × 0.0369 = 8.13 × 0.0369 = 0.300 kg
• TDNImilk = MY × 0.20 = 8.13 × 0.20 = 1.626 kg
• MCP = -53.07 + 304.89 × (CPI – CPImilk) + 90.79 × (TDNI – TDNImilk) – 3.13 × $(TDNI – TDNImilk)^2$ = -53.07 + 304.89 × (0.459 – 0.300) + 90.79 × (2.29 – 1.626) – 3.13 × $(2.29 – 1.626)^2$ = 73.8 g/d
• RDP = MCP = 73.8 g/d
• RUP = (MPt – (MCP × 0.64))/0.80 = (356.4 – (73.8 × 0.64))/0.80 = 385 g/d
• CP = RDP + RUP = 73.8 + 385 = 459 g/d

In the same way as for cows, to obtain the concentration required of TDN and CP (% DM in the diet), the requirements of TDN (2.29 kg/d) and CP (459 g/d) can be divided by DMI of the animal.

• TDN (% DM in the diet) = TDN/DMI = 2.29/2.78 = 82.4%
• CP (% DM in the diet) = PB/DMI = 0.459/2.78 = 16.5%

- Mineral requirements (Table 11.11):
• Calcium:
- Net requirements for maintenance: 11.7 × 150/1000 = 1.755 g/d
- Net requirements for growth = EBG × (54.8 × $EBW^{-0.3981}$) = 0.77 × (54.8 × $144^{-0.3981}$) = 5.835 g/d
- Dietary requirements = (Net requirements for maintenance + growth)/retention coefficient = (1.755 + 5.835)/0.568 = 13.36 g/d

• Phosphorus:
- Net requirements for maintenance: 13.5 × 150/1000 = 2.025 g/d
- Net requirements for growth = EBG × (8.6 × $EBW^{-0.0371}$) = 0.77 × (8.6 × $144^{-0.0371}$) = 5.507 g/d
- Dietary requirements = (Net requirements for maintenance + growth)/retention coefficient = (2.025 + 5.507)/0.678 = 11.11 g/d

Ca:P ratio= 13.36/11.1 = 1.20

• Magnesium:
- Net requirements for maintenance: 5.9 × 150/1000 = 0.885 g/d
- Net requirements for growth = EBG × (0.4 × $EBW^{-0.0173}$) = 0.77 × (0.4 × $144^{-0.0173}$) = 0.282 g/d
- Dietary requirements = (Net requirements for maintenance + growth)/retention coefficient = (0.885 + 0.282)/0.355 = 3.29 g/d

• Sodium:
- Net requirements for maintenance: 6.3 × 150/1000 = 0.945 g/d
- Net requirements for growth = EBG × (1.2 × $EBW^{-0.0209}$) = 0.77 × (1.2 × $144^{-0.0209}$) = 0.833 g/d
- Dietary requirements = (Net requirements for maintenance + growth)/retention coefficient = (0.945 + 0.833)/0.371 = 4.79 g/d

• Potassium:
- Net requirements for maintenance: 23.5 × 150/1000 = 3.525 g/d
- Net requirements for growth = EBG × (1.5 × $EBW^{-0.0636}$) = 0.77 × (1.5 × $144^{-0.0636}$) = 0.842 g/d
- Dietary requirements = (Net requirements for maintenance + growth)/retention coefficient = (3.525 + 0.842)/0.484 = 9.02 g/d

We highlight that there are no studies that aimed to evaluate dietary requirements of S and microminerals for this animal category, being suggested the use of same recommendations from the Chapter 9.

Table 11.11 - Energy and protein requirements and dietary requirements of macrominerals (Ca, P, Mg, Na, and K) for suckling beef calves

Requirements	Body weight (kg)											
	100			150			200			250		
ADG (kg/d)	0.60	0.80	1.00	0.60	0.80	1.00	0.60	0.80	1.00	0.60	0.80	1.00
DMI (kg/d)	2.18	2.25	2.32	2.71	2.78	2.85	3.24	3.31	3.38	3.78	3.85	3.92
Energy (Mcal/d)												
NEm		2.16			2.93			3.63			4.29	
MEm		3.64			4.94			6.13			7.24	
NEg	1.72	2.24	2.75	2.34	3.04	3.73	2.90	3.77	4.63	3.43	4.46	5.47
MEg	2.61	3.40	4.17	3.65	4.75	5.83	4.60	5.99	7.35	5.55	7.22	8.86
MEt	6.26	7.04	7.81	8.59	9.69	10.8	10.7	12.1	13.5	12.8	14.5	16.1
TDN (kg/d)	1.48	1.67	1.85	2.03	2.29	2.55	2.54	2.87	3.19	3.03	3.42	3.81
Crude protein (g/d)												
MPm		123			167			207			245	
NPg	94.3	126	157	95.6	127	159	96.6	129	161	97.3	130	162
MPg	129	171	214	141	188	236	156	208	260	173	230	288
MPt	252	295	338	308	356	403	363	415	467	418	476	533
RDP	0.00	5.00	27.0	30.7	73.8	116	117	167	216	200	257	311
RUP	315	364	400	361	385	411	360	385	411	362	389	418
CP	315	369	427	392	459	527	478	552	627	563	646	729
Macrominerals (g/d)												
Ca	11.1	14.1	17.1	10.8	13.36	15.9	11.0	13.2	15.5	11.4	13.5	15.6
P	8.15	10.2	12.2	9.05	11.11	13.1	9.98	12.0	14.0	10.9	12.9	14.9
Mg	2.26	2.46	2.66	3.09	3.29	3.48	3.92	4.11	4.31	4.74	4.94	5.14
Na	3.39	3.95	4.51	4.22	4.79	5.34	5.06	5.62	6.17	5.90	6.46	7.01
K	6.19	6.63	7.08	8.58	9.02	9.45	11.0	11.4	11.8	13.4	13.8	14.2

[1] BW = SBW; To convert NEg for MEg, the following kg were utilized as a function of body weight of the animals: 100 kg – 0.66, 150 kg – 0.64, 200 kg – 0.63, and 250 kg – 0.618; [2]Considering milk yield in the following weeks: 10th – 8.13 kg/d (100 kg BW); 19th – 7.51 kg/d (150 kg BW); 28th – 6.89 kg/d (200 kg BW); and 37th – 6.27 kg/d (250 kg BW).

SUPPLEMENTATION OF CALVES DURING BREAST-FEEDING PERIOD

From the information generated in the studies of Fonseca (2009) and Costa e Silva et al. (2015a), or so, considering the lactation curve of Nellore cows, the average milk composition, and according to nutrient requirements obtained for calves through breast-feeding phase, we will be able to estimate the moment when milk is not sufficient to provide nutrient demanded for calf growth. Also, considering energy and protein as the most limiting nutrients, we showed that after the 12th week or so, at around 84 days of age, the milk does not provide all of the energy necessary for the calf which has an ADG close to 1 kg/d. However, protein becomes limiting only after the 20th week, approximately 140 days of age, which would be around from 70 to 100 days before weaning. Therefore, with the aim being for Nellore calves to maintain body weight gain close to 900 g/d until weaning, we recommend the use of multiple supplements via creep feeding after the third month of age, or then, to utilize cows with greater potential for milk yield (Table 11.12).

Table 11.12 - Milk yield of Nellore cows, availability of metabolizable energy (ME) and protein (MP) from milk, total requirements of ME and MP of suckling Nellore calves, and the need of milk to meet the ME requirements of calves according to the week of lactation and the body weight of the animals

W[1]	BW[2]	MY[3]	ME milk[4]	MP milk[5]	MEt[6]	MPt[7]	NM[8]
1	35.6	8.39	6.38	197	2.82	58.5	3.70
2	41.2	8.67	6.59	204	3.14	65.3	4.13
3	46.8	8.61	6.54	202	3.46	71.8	4.55
4	52.4	8.54	6.49	201	3.76	78.1	4.95
5	58.0	8.47	6.44	199	4.06	84.3	5.34
6	63.6	8.40	6.39	197	4.35	90.3	5.73
7	69.2	8.34	6.34	196	4.64	96.2	6.10
8	74.8	8.27	6.28	194	4.91	102	6.47
9	80.4	8.20	6.23	193	5.19	108	6.83
10	86.0	8.13	6.18	191	5.46	113	7.18
11	91.6	8.06	6.13	189	5.72	119	7.53
12	97.2	7.99	6.07	188	5.98	124	7.87
13	103	7.92	6.02	186	6.24	129	8.21
14	108	7.85	5.97	184	6.49	135	8.54
15	114	7.78	5.92	183	6.74	140	8.87
20	142	7.44	5.65	175	7.95	165	10.5

[1]W = week of lactation; [2] BW = body weight of calf, kg: considering body weight at birth of 30 kg and ADG of 0.80 kg/d; [3]MY = milk yield; [4] ME milk: amount of metabolizable energy available to calf from milk (Mcal/d); [5]MP milk: amount of metabolizable protein available to calf from milk (g/d); [6]MEt = total requirements (maintenance + growth) of metabolizable energy of calf; [7]MPt: total requirements (maintenance + growth) of metabolizable energy of calf; [8]NM: need of milk (kg/d) to meet total requirements of ME of calf. Adapted from the BR-CORTE (2010).

The greater genetic capacity of cows leads to greater milk production, enabling an increase on weaning weight of calves. However, we should not disregard that the nutritional levels in the majority of pasture systems limits higher levels of milk yield (Paulino et al., 2012). Additionally, in the 3rd and 4th months of age, there are considerable changes through the gastrointestinal tract of the calf, and this is the period when this animal turns effectively ruminant (Porto et al., 2009), making it more dependent on pasture. However, these processes occur during the rainy-dry transition period in the most of Brazilian production systems, which causes a decrease in quality and quantity of forage available for grazing. Consequently, the difference between the nutrient requirements of the calf and the amount of nutrients supplied by milk and pasture tends to increase, causing an unfavorable situation in calves concerning nutrient balance. Thus, for the intensive production systems of cattle, which require greater nutrient supply, the supplementation of suckling calves under a creep feeding system is recommended. Creep feeding refers to the supply of additional feed for animals during the breast-feeding phase in a restricted area for calves (Paulino et al., 2012).

Studies regarding creep feeding in tropical conditions have consistently shown an increase in BW at weaning (Table 11.13), showing the importance of creep feeding to reduce the age at slaughter and the beginning of reproduction activity for animals raised on grazing conditions (Paulino et al., 2010). However, the additional body weight gain with the use of creep feeding is variable. Factors such as the amount and quality of pasture, milk yield of cows, growth potential of calves, breed, sex, age of calves at weaning, and even the type of supplement and time of use of creep feeding influence animal performance.

Table 11.13 - Summary of data from studies about creep feeding

Study[1]	Experimental period (d)	Calf´s sex	Supplement intake (g/d)[2]	CP content in the supplement (g/kg)	ADG[3]	
					NS	SUP
De Paula et al. (2012)	112	Male	583	300	662	728
Valente et al. (2013)	112	Male	530	150-550	608	804
Barros et al. (2014)	112	Female	500	250	687	769
Lopes et al. (2014)	140	Male	900	80-410	727	880
Cardenas et al. (2015)	140	Female	500	80-400	619	677
Barros et al. (2015)	140	Male	850	250	731	843
Marquez et al. (2014)	150	Female	450	250	628	677
Lopes (2015)[4]	140	Male	1200	250	720	873
Almeida (2016)[4]	140	Female	800	250	642	732
Martins (2016)[4]	140	Male	1600	250	500	900

[1]Data processed; to access individual data, consult references.
[2]Mean intake of supplement from supplemented animals.
[3]ADG = average daily gain (g/d), NS = calves that received only mineral supplementation; or SUP = calves that received multiple supplements in a creep feeding system.
[4]Work in progress.

Then, when the limit imposed by genetics is obeyed, the lower pasture capacity and/or milk yield in meeting the nutritional requirements of calves, the greater will be the response to creep feeding, reflecting positively on the efficiency and profitability of this technique.

However, recommending the best level of supplementation (% BW) and the best CP content in the concentrate is difficult as this combination is inversely proportional; when the aim is to provide lower amounts of supplement, the CP content might be greater and the inverse is true. Therefore, the amount of supplement and CP content will depend directly on the aim of the production system.

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