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Nutritional requirements for pregnant and non-pregnant beef cows

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INTRODUCTION

The only category that was lacking minimal knowledge about nutritional requirements of Zebu cattle is the pregnant cows. Although the importance of knowing the nutritional requirements of this category is clear, no study published prior to 2013 had quantified the nutritional requirements for Zebu cows maintenance and pregnancy. The first study designed to assess the nutritional requirements of adult Zebu cows was carried out in Brazil from 2010 to 2013, and the results form the basis of this chapter.

It is estimated that the Brazilian beef cow herd, though fluctuating, ranges from 65–70 million (ANUALPEC, 2015), resulting in a total herd of more than 210 million heads (IBGE, 2015). That is, numerically, about one-third of the Brazilian herd consists of cows, and the great majority is Zebu. As they are adult animals and are permanently in the system, the energy expenditure in the productive system and area used by these cows are fairly significant portions of the total used for beef production in Brazil. Several publications have already reported that the energy spent by the reproduction herd of beef cattle represents about 70% of the total energy spent for the entire system (Ferrell and Jenkins, 1984a; Ritchie, 1995). Something close to 50% of the energy of the system is spent on adult cow maintenance (Ferrell and Jenkins, 1984b).

We therefore needed to define references for nutritional levels for adult beef cows. Based on the current mean productive indexes of beef cattle herds in Brazil (Baruselli et al., 2012; ABIEC, 2013; Jank et al., 2014; Chiavegato et al., 2015), it is estimated that there is potential for 30–40% improvement in the production efficiency of beef calves (Gionbelli et al., 2015c), considering joint improvements in nutrition, reproduction and genetics.

Other feeding systems in use in the world (ARC, 1980; AFRC, 1993; NRC, 2000; CSIRO, 2007; INRA, 2007) base their recommendations to meet pregnant cow nutritional requirements on a few studies carried out previously or on indirect estimates and adaptations of values obtained in experiments involving other ruminant categories or species. The ARC (1980) based their recommendations in a study involving Ayrshire and Jersey cows carried out in 1975 and the AFRC (1993) did not adopt significant updating on how to calculate nutritional requirements for pregnancy. The NRC (2000) based its recommendations on studies by Calvin Ferrell and collaborators (Ferrell et al., 1976a; Ferrell et al., 1976b; Ferrell et al., 1976c) on Hereford animals, and it is one of a few experiments known in which there was comparative slaughter of pregnant cows. Furthermore, the NRC (2000) presented suggestions for adjustments based on the study by Prior and Laster (1979), which were carried out with Brown Swiss animals. The French system (INRA, 2007) published estimates for nutritional requirements during pregnancy in 1978. These recommendations were based on a study by Ferrell et al. (1976c) and a study on cattle fetus chemical composition (Cano, 1995). The recommendations for nutritional requirements during pregnancy presented by the Australian system (CSIRO, 2007) are based on the indexes made by the ARC (1980) and adjustments and adaptations of studies carried out on sheep, of which there are a greater number in the literature.

The present chapter will present the results of recent research carried out in Brazil to estimate the nutritional requirements for energy and protein for adults Zebu cows for maintenance and pregnancy. Discussions on the physiological aspects related to nutrient breakdown by pregnant cows as a function of homeorhesis, and review of the impacts of not meeting the nutritional requirements of pregnant cows on cattle progeny development are also presented

METHODOLOGY USED TO ESTIMATE THE REQUIREMENTS

It is known, clearly, that female pregnant mammals break down available nutrients to favor their offspring. This concept was first presented by Hammond (1947), who suggested that different tissues compete for circulating nutrients based on their respective metabolic rates. This idea was reinforced by the discovery of high metabolism rates in the gravid uterus as compared to the maternal body (Meschia et al., 1980). However, recent research has concentrated on the endocrine regulation of the tissues instead of competition as a general explanatory mechanism (Bauman, 2000; Mamontov, 2007). This way of thinking comes in the concept of "homeorhesis", elaborated by Bauman and Currie (1980). This concept suggests that there is simultaneous influence from multiple tissues implying extracellular mediation so that the metabolism meets the demands more coherently at levels that optimize the opportunity for the fetus to grow and survive after calving, and minimizing the excessive depletion of maternal energy and protein reserves.

Although there are mathematical models attempting to explain homeorhesis (Mamontov, 2007; Psiuk-Maksymowicz and Mamontov, 2008), their application to nutrient breakdown in pregnant cows is still far from what could be proposed to estimate nutritional requirements. It is known that there is wide interaction between maternal tissues and the gravid uterus that implies modification in the efficiency of use of the nutrients on the part of the maternal tissues. However, the base for estimating nutritional requirements for pregnant cows that will be used here is a factorial model, where requirements for maintenance, body reserve accumulation, gravid uterus growth and fetus formation do not interact but, rather, are considered additive. This methodology is similar to those used by the other nutritional systems. Therefore additional requirements will be presented for pregnancy in Zebu cows, in addition to the requirements for maintenance and body reserve accumulation. This does not mean, however, that the estimates used are not accurate. The methodology used here permits to estimate that the quantitative result of the interaction between maternal and gestation tissues is calculated as requirements for pregnancy, adding to the net accumulation in gestation tissues and the expenditure to synthesize the gestation tissues.

The base experiment of this chapter was carried out at the Federal University of Viçosa (UFV), from 2010 to 2011. (Gionbelli, 2013). Forty-nine Zebu cows, predominantly Nellore, were obtained from the UFV herd and from two other commercial herds, with the objective of representing the Brazilian beef cattle herd. These cows were used in a comparative slaughter experiment, with a design similar to that of the study carried out by Dr. Calvin Ferrell and collaborators (Ferrell et al., 1976a; Ferrell et al., 1976b; Ferrell et al., 1976c). The study estimated the nutritional requirements of pregnant cows in feed systems that use taurine cattle. A group of 17 cows was kept under the same treatment as the other 32 pregnant cows (at different feed levels), to estimate comparatively the requirements for maintenance, maternal tissue gain and pregnancy. The 32 cows were slaughtered at four different stages of pregnancy (136, 189, 239 and 269 d pregnant) to assess nutrient and energy accumulation in the gravid uterus and maternal tissues, and thus mathematical models were fitted that could be used to estimate the net requirements for pregnancy.

The concept of pregnant compound was adopted (PREG) to estimate the energy and protein accumulation rate related to pregnancy or to the maternal tissues, presented by Gionbelli et al. (2015a) and discussed in Chapter 1. The PREG represents the true quantities of components that grow directly related to pregnancy. This includes the gravid uterus less the estimated weight of the non-gravid uterus plus the growth of the mammary gland related to pregnancy. Thus, the energy and protein quantities in the total body of a pregnant cow follow the ratio:

$$CTB = MT + PREG \qquad \text{Eq. 10.1}$$

where CTB = cow´s total body, MT = maternal tissues (carcass, viscera, leather, blood, head, hooves, udder, besides the non-gravid uterus less the addition of the udder related to pregnancy) and PREG = pregnant compound.

The estimates for the nutritional requirements for pregnant and non-pregnant Zebu cows discussed next are derived from recently published studies (Gionbelli, 2013; Gionbelli et al., 2013; Gionbelli et al., 2014; Gionbelli et al., 2015a; Gionbelli et al., 2015b).

DRY MATTER INTAKE IN ADULT ZEBU COWS

In simple-stomach mammals, feed intake increases during pregnancy to coincide with the high nutritional requirements of large litters or even a single fetus. In pigs, this effect is very pronounced, to the point that fiber-rich diets are adopted to prevent excessive increases in body fat (Forbes, 2007). In ruminants, it is suggested that the females can increase voluntary feed intake in half of the gestation, but this increase is much lower than in pigs and very often is not observed (Ingvartsen and Andersen, 2000). Forbes (1996) also reported that cows and sheep tended to increase, because they were more selective, voluntary intake of feeds of higher nutritional quality when close to the end of pregnancy. However, there is a marked reduction in intake during the final weeks of pregnancy in cattle.

Ingvartsen et al. (1992) showed a table containing 20 groups of cows from nine publications, where variations were observed in intake in the last weeks ranging from 0.2% increase/week to 9.4% reduction /week. The same authors also verified that heifers reduced voluntary intake by 1.53%/week in the last 14 weeks pregnant, and this rate increased in the last two weeks, and there was an approximate 30% reduction in the five d preceding calving. The variations observed in intake during pregnancy can also be different for cow and heifers (Ingvartsen and Anderson, 2000).

Intake regulating factors in pregnant cows

Feed intake regulation by pregnant cows can present physical and physiological factors that are not considered in traditional models of feed intake regulation in ruminants (Forbes, 1980; Fisher et al., 1987). These aspects, such as the influence of the calf weight on reducing the rumen capacity, hormone regulation of pregnancy, or even the homeorhetic mechanism of using nutrients, are difficult to model and are the main causes of the variation in voluntary intake observed at this physiological stage of cattle. The various factors involved in regulating feed intake by pregnant cows include:

Physical factors: it has been suggested that reduced feed intake, observed in late pregnancy, may be caused by compression of the rumen by the growing uterus and aggravated by abdominal fat (Forbes, 2007). The displacement of the rumen as a function of fetus growth in sheep was graphically illustrated by Forbes (1968), who slaughtered ewes at different stages of pregnancy, froze the whole carcasses, and then cross-sectioned and photographed the abdomen. Forbes (1969) observed a negative relationship between the volume of ruminant content at slaughter (VR, liters) and the volume of compressible ruminal content (gravid uterus + abdominal fat, CCR, liters), in ewes fed hay, following the ratio: $VR = 10.3 - 0.37 \times CCR$. Further in the same study, the dry matter intake (DMI, kg/d) during the last two weeks before slaughter was positively related to the VR (liters) at slaughter: $DMI = 0.48 + 0.033 \times VR$. The reduction in feed intake was proportionally lower than that of the rumen volume, probably as a result of increased passage rate as a compensation factor for the reduction in ruminant volume. Later, other studies (Kaske and Groth, 1997; Gunter et al., 1990; Coffey et al., 1989) confirmed the theory that pregnancy increases the digestive passage rate in sheep, probably as a compensating factor for rumen compression by the gravid uterus.

Lagerlof (1929) reported increased quantities of abdominal fat and physical compression of the rumen by the uterus in cows. Lamberth (1969) carried out two experiments to compare the effect of pregnancy on dry matter voluntary intake, digestibility and passage rate in heifers. The two experiments were carried out using pairs of twin heifers, and one of each pair was pregnant and the other was open. The dry matter digestibility was decreased in pregnant heifers, also causing a reduction in the digestible dry matter intake. Measurements of rumen volume and passage rate did not give conclusive results.

This information gives sufficient evidence that there is a physical effect from pregnancy on reducing dry matter intake by cows and ewes in late pregnancy. But it is unlikely that the decrease in ruminant volume is the only cause for reducing feed intake. Coppock et al. (1974) observed that reduction in dry matter intake by cows in late pregnancy was more pronounced when the diet contained high concentrate contents as compared to diets with lower contents. Therefore, it is probable that other factors are also involved in reducing intake in late pregnancy. Furthermore, it is important to observe that the effects of physical compression coincide with the changes in the endocrine factors and body reserves, mediated in response to the advance of the pregnancy and preparation for future lactation.

At the time of calving, the abdominal cavity is reduced in size due to the exit of the amniotic liquid, fetus and fetal membranes. This decrease is approximately 70 kg for dairy cows and 50 kg for beef cows. The disappearance of such a large mass from the abdominal cavity should permit rapid increase in voluntary feed intake in the first d after calving, if physical compression was the only factor that caused decrease in intake. Generally, no rapid increase in dry matter intake is observed shortly after calving, and the increase is relatively slow, even in relation to the increase in milk production (Friggens et al., 1998).

Physiological factors: several endocrine, metabolic and behavioral factors are related to variation in feed intake during pregnancy in cows. It is suggested that the main hormone acting on reducing intake is estrogen (Forbes, 2007). At the time of estrus of the cow, an estrogen peak coincides with low feed intake that in this case is temporary (Forbes, 2007). During pregnancy however, the plasma estrogen levels increase to about 300 pg/ml during the first pregnancy semester and remain stable until a month after the calving, when the levels rise to 4000-6000 pg/ml in the last d before calving. This increase in the d that proceed calving is correlated with reduction in intake.

Progesterone seems not to have a direct effect on feed intake in cattle (Ingvartsen and Andersen, 2000), but, because it blocks estrogen effects (Gagliostro et al., 1991), it may reduce the effects of this on feed intake. Bargeloh et al. (1975) administered 0.25 mg/BW/d progesterone in cows in late pregnancy and observed bigger dry matter intake in the treated cows as compared to those not treated (17.1 kg/d vs 11.7 kg/d, respectively) in the last six days pregnant. Pregnancy was also prolonged in some cows that received the progesterone doses, causing problems and hindering commercial use of some of this type of hormone infusion.

Metabolic factors: an imbalance among nutrients required by the mother and the fetus during late pregnancy can also reduce feed intake by female ruminants during this phase. Barry and Manley (1986) administered glucose and casein in the abomasum of pregnant ewes and observed increases in voluntary intake four weeks before lambing in the administered ewes. Later, there was a more pronounced reduction in intake than in the animals that did not receive glucose and casein. The authors suggested that the effect of greater intake in the administered animals caused greater pre-natal reduction in intake, while for the non-infunded animals intake was limited by diet imbalance and other factors present at the end of the pregnancy.

Behavioral factors: concern and discomfort with the need to search for an adequate place for calving are also suggested as factors that reduce feed intake by pregnant cows in late pregnancy. Endocrine changes associated with calving (corticosteroids, prostaglandins, oxytocin, relaxin, etc.) may also be related (Forbes, 2007).

Dry matter intake by pregnant Zebu cows

A graphic representation of dry matter intake (DMI) by pregnant Zebu cows is shown in Figure 10.1 (Gionbelli, 2013). The effect of pregnancy on voluntary dry matter intake was assessed comparing intake of pregnant and open cows receiving a diet with high bulk level (85%) for a similar period of duration. Segmented models were fitted to verify decrease in DMI after a determined period of pregnancy. Linear reduction was observed (quadratic and cubic effects were also tested) in dry matter intake in proportion to the body weight by pregnant Zebu cows ($P<0.05$) starting at 131 d pregnant (decrease of 0.0204 grams of dry matter per kg SBW for each d pregnant over 135 d). As described in the later items, for this edition of the BR-CORTE, it was chosen to consider the requirements for pregnancy in Zebu cows after 135 d pregnant (4.5 months). Thus a model of DMI reduction as a function of d pregnant was fitted for adult Zebu cows, starting at 135 d of pregnancy. Therefore, the equations proposed to describe the DMI of pregnant Zebu cow should be:

$$DMIpreg\ (g/SBW) = DMInp - 0.02 \times (TG - 135) \quad \text{Eq. 10.2}$$

$$DMIpreg\ (kg/d) = DMInp - (SBW \times 0.00002 \times (TG - 135)) \quad \text{Eq. 10.3}$$

where: DMIpreg = dry matter intake after 135 d pregnant (in g/SBW or in kg/d), DMInp = dry matter intake in non-pregnant condition or up to 135 d pregnant (in g/SBW for Eq. 10.2 and in g/d for Eq. 10.3), TG = days pregnant and SBW = shrunk body weight (kg).

The equations presented above can be used for any herd in any situation, because they involve only fitting dry matter intake as a function of the advance of the pregnancy. There is no standardized equation with which to estimate the dry matter intake of adult non-pregnant Zebu cows that depends on the characteristics of the animal and forage quality and availability (and supplementation).

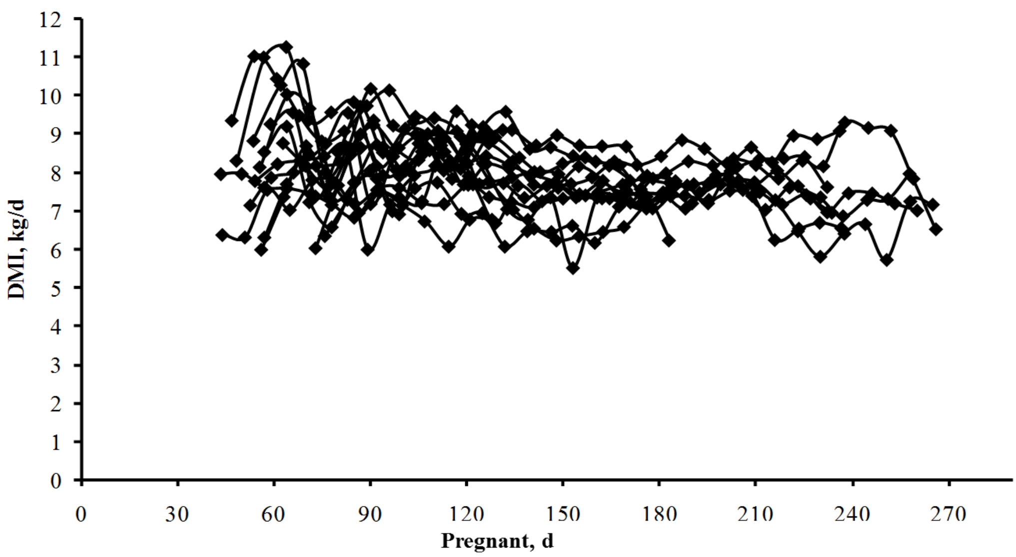

Figure 10.1 - Relationship between dry matter intake and days pregnant in Zebu cows.

REQUIREMENTS FOR MAINTENANCE

Energy requirement for maintenance

The net energy requirements for maintenance (NEm, kcal/$EBWnp^{0.75}$/d) were estimated from the ratio between heat production (HP, kcal/$EBW^{0.75}$/d) and metabolizable energy intake (MEI, kcal/$EBW^{0.75}$/d), using an exponential model, in the same way as for growing and finishing animals. The following model was obtained based on data reported by Gionbelli (2013):

$$HP = 85.9 \times \exp^{(MEI \times 0.0028)}$$
Eq. 10.4

The NEm value corresponds to the intercept of Eq. 10.4, representing the quantity of heat produced in absolute fasting. Further based on Eq. 10.4, the metabolizable energy requirements for maintenance (MEm, kcal/EBWng$^{0.75}$/d) are estimated, by an iterative process to equal the HP and MEI. The MEm is the point at which the heat produced by the animal is equal to the metabolizable energy consumed. Thus, the NEm and MEm values for adult Zebu cows can be obtained by the models presented below:

$$\text{NEm (kcal/d)} = 85.9 \times EBW^{0.75}$$
Eq. 10.5

$$\text{MEm (kcal/d)} = 120 \times EBW^{0.75}$$
Eq. 10.6

where EBW = empty body weight (kg).

The partial efficiency of use of metabolizable energy for maintenance (*km*) is obtained from the NEm/MEm ratio (85.9/120), corresponding to 0.72 or 72%. Since it is very difficult to model the metabolizable energy requirements for maintenance for pregnant cows, similar to Ferrell et al. (1976c), it is assumed that the *km* does not vary among pregnant and open cows. Robinson et al. (1980) also suggested that the *km* value is similar among gestating animals and other categories.

The experiment used as base to estimate the metabolizable requirement for Zebu cows (Gionbelli et al., 2015a) was carried out with feedlot cows to ensure the experimental control necessary for a study of this type. The energy requirement estimates presented in Chapter 7 show that pastured-raised beef cattle under tropical conditions MEm 8.5% higher to those reared on feedlot. As beef cows are routinely kept on pasture in tropical conditions, an 8.5% increase is suggested in the MEm value calculated for this category (120 × 1.085):

$$\text{MEm (kcal/d)} = 130 \times EBW^{0.75}$$
Eq. 10.7

where EBW = empty body weight (kg).

The MEm value established for open and pregnant Zebu cows in this edition of the BR-CORTE (Eq. 10.7) is equal to the MEm of a growing Zebu heifer, with 0.375 kg average daily gain (*km*, used to calculate the MEm in growing animals takes into consideration the weight gain rate – see Chapter 7). A growing heifer with 1 kg average daily gain has MEm equal to 119 kcal/EBWnp$^{0.75}$/d, a lower value than the MEm of an adult open or pregnant cow.

Although there is evidence that requirements for maintenance (per metabolic size unit, EBW$^{0.75}$) can reach up to 50% in late pregnancy in beef cattle (Brody, 1945; Ferrell et al. 1976c; BCNRM, 2016), such an increase has not been directly considered in comparative slaughter experiments carried out on pregnant cows (Ferrell et al. 1976c; Gionbelli et al. 2015b). In these cases, the additional energy spent on maintenance relative to pregnancy is quantified in the calculation of the nutritional requirements for pregnancy. Thus it becomes possible to calculate separately the nutritional requirements in a factorial manner, for maintenance, maternal tissue accumulation and pregnancy, as previously discussed.

When compared to the MEm for lactating Zebu cows (135.4 kcal/EBW$^{0.75}$/d; see Chapter 11), the MEm value presented for open or pregnant cows is 4% lower. A compilation of the of studies carried out by the BCNRM (BCNRM, 2016) suggests that the maintenance requirement for lactating cows is about 20% higher (10 to 49% variation) than for beef cattle breed non-lactating cows.

The MEm values estimated for open and pregnant Zebu cows are about 5% lower than the MEm values estimated for taurine cows (Angus-Hereford crossbreds) of the same category (Table 10.1). Comparing to the ME values estimated for large size (continental) taurine cows, the ME values of open and non-lactating Zebu cows are about 14% lower, for cows of the same weight (considering data by C.L. Ferrell and T.G. Jenkins, unpublished, quoted in the BCNRM, 2016).

Table 10.1 - Metabolizable energy requirements for maintenance, estimated for Zebu and taurine beef cows with 450 and 600 kg body weight, respectively

Sub-species	BW, kg	SBW, kg	EBW, kg	$EBW^{0.75}$, kg	MEm, Mcal/d	%
Bos taurus indicus	450	438[1]	397[3]	89[5]	11.6[5]	94[7]
Bos taurus taurus	450	432[2]	368[4]	98[6]	12.3[6]	100
Bos taurus indicus	600	589[1]	536[3]	111[5]	14.5[5]	95[7]
Bos taurus taurus	600	576[2]	490[4]	121[6]	15.3[6]	100

BW = body weight, SBW = shrunk body weight, EBW = empty body weight, MSU = metabolic size unit and MEm = metabolizable energy requirement for maintenance; [1] $SBW = 0.8084 \times BW^{1.0303}$ (see Chapter 1); [2] $SBW = 0.96 \times BW$ (NRC); [3] $EBW = 0.8424 \times SBW^{1.0122}$ (see Chapter 1); [4] $EBW = 0.851 \times SBW$ (NRC); [5] $EMm = 1.30 \times EBW^{0.75} / 1000$; [6] $EMm = 1.26 \times BW^{0.75} / 1000$. for Angus-Hereford cow data by C.L. Ferrell and T.G. Jenkins, unpublished, quoted in the NRC (2000); [7] As % of taurine cow MEm.

Protein requirements for maintenance

Similar to the energy requirements for maintenance, the protein requirements for maintenance were calculated from the database of open and non-lactating cows in the experiment by Gionbelli (2013). The metabolizable protein requirement for maintenance (MPm, g/d) was obtained from the relationship among metabolizable protein intake (MPI, g/d), protein retained in maternal tissues (RP_{MT}, g/d) and metabolic shrunk body weight ($SBW^{0.75}$, kg), as shown in Eq. 10.8. Based on Eq. 10.8, the MPI necessary to maintain the protein body content stable is equal to 3.93 grams per kg $SBW^{0.75.}$ that is the MPm value for open and non-lactating Zebu cows. This value is very close to the MPm value recommended for growing animals raised on pasture (see Chapter 8, MPm, g/d = $3.9 \times SBW^{0.75}$). Due to the small numerical difference, the same MPm value is also suggested for Zebu cows (Eq. 10.9).

$$MPI\ (g/d) = 3.93 \times SBW^{0.75} + 2.63 \times RP_{MT} \quad \text{Eq. 10.8}$$

$$MPm\ (g/d) = 3.9 \times SBW^{0.75} \quad \text{Eq. 10.9}$$

where MPI = metabolizable protein intake (g/d), SBW = shrunk body weight (kg) and RP_{MT} = retained protein in the maternal tissues (g/d).

REQUIREMENTS FOR MATERNAL TISSUE GAIN

The nutritional requirements for maternal tissue gain were estimated according to the daily maternal tissue accumulation rate (ADG relative to maternal tissue - see Chapter 1) and the body condition score (BCS). Therefore the estimates can be used for herds with variable weights at maturity. In spite of representing a parameter of a set of subjective assessments, the BCS is a tool with great practical and proven significance related to the variations in the body composition of adult cows (NRC, 2000).

It should also be pointed out that the requirements for weight gains of pregnant and open cows are considered similar, although there may be an effective homeorhetic metabolism (Hammond, 1947). However, Gionbelli et al. (2015b) did not observe effect of pregnancy on the dynamic of maternal tissue deposition (P = 0.388), indicating that quantitatively, the composition of maternal tissue gain in pregnant and open cows is similar. This sustains the use of the factorial model to calculate the nutritional requirements of Zebu cows, in which requirements for maintenance, maternal tissue gain and pregnancy are calculated independently and added to calculate the total requirements.

Energy requirements for gain

The net energy nutritional requirements for adult cow weight gain (NEg, Mcal/d), are calculated by the following equation:

$$NEg\ (Mcal/d) = 3.82 \times EBGnp^{1.07} \times BCS^{0.35} \quad \text{Eq. 10.10}$$

where EBGnp = non-pregnant empty body weight gain (kg), that considers the weight gain for maternal tissues of the cow (for open cows it is equal to the EBG) and BCS = body condition score (scale 1 to 9).

Based on Eq. 10.10, the net energy required for weight gain of two adult cows, with

5 BCS, but with different weights (ex.: 500 and 600 kg) is the same, because it is assumed that the body composition of both is proportional to the BCS and if the weight of the same BCS is different, it means that the mature weight of its herd is different. This occurs when the NEg is calculated based on the variations in the body composition and, consequently on the gain composition. The exponential 1.07 of the EBG means that the gain composition varies as a function of the daily reserve accumulation rate. For higher ADG rates, a higher proportion of fat will be deposited and consequently, the NE will be greater for each kilo of gain. An example of applying Eq. 10.10 is shown in Table 10.2.

Table 10.2 - Net energy requirements for weight gain of adult cows with different body condition scores and different weight gain rates

BCS	ADG, kg	EBG, kg[1]	NEg, Mcal/d	NEg, Mcal/kg EBG
3	0.2	0.19	0.94	4.99
3	0.5	0.48	2.54	5.33
3	0.8	0.77	4.23	5.51
5	0.2	0.19	1.12	5.97
5	0.5	0.48	3.04	6.37
5	0.8	0.77	5.06	6.59
7	0.2	0.1.9	1.26	6.71.
7	0.5	0.48	3.41	7.17
7	0.8	0.77	5.69	7.41

BCS = body condition score, ADG = average daily gain, EBG = empty body weight gain and NEg = net energy requirement for weight gain; [1.]EBG = $0.963 \times ADG^{1.0151}$ (see Chapter 1).

The energy concentration in the weight gain for adult cows presented in Table 10.2 is usually larger for growing animals (Chapter 7) for BCS $\geq$ 4. Cows with BCS < 4 have a considerable proportion of lean tissue in the gain composition. This fact occurs probably because although they have theoretically reached physiological maturity, the quantity of skeletal muscle tissue in the carcass is below the usual, due to mobilization to meet the requirements of pregnancy, lactation or even maintenance. There is evidence of large skeletal muscle tissue mobilization in the carcass of adult female ruminants to meet the high demand for amino acids by the placenta in the final stages of pregnancy (Bell et al., 2000; Bell and Ehrhardt, 2000; Bell et al., 2005).

The net energy requirements for reserve accumulation presented here for Zebu cows are similar to those for taurine cows presented by the NRC/BCNRM System (BCNRM, 2016), considering the BCS variations. According to the BCNRM (2016), an adult cow with BCS = 5, regardless of weight at maturity, requires 6.38 Mcal for each kg EBG. The data presented in the present edition of the BR-CORTE for Zebu cows show that an adult Zebu cow with BCS = 5, regardless of weight at maturity, requires between 5.97 and 6.69 Mcal per kg EBG, depending on the weight gain rate (in this case, 5.97 Mcal/kg EBG for EBG = 0.2 kg/d and 6.69 Mcal/kg EBG for EBG = 1.0 kg/d). This variation in the gain composition as a function of the gain rate, however, is not considered by the BCNRM System.

The partial efficiency for conversion of metabolizable energy to net energy (*kg*) for weight gain suggested for adult Zebu cows is 0.53 (Gionbelli et al., 2015b). Thus the metabolizable energy requirements for maternal tissue weight gain (MEg, Mcal/d) for adult Zebu cows can be calculated according to Eq. 10.11:

$$MEg\ (Mcal/d) = NEg/0.53 \quad \text{Eq. 10.11}$$

where NEg = net energy requirement for gain (Mcal/d).

Protein requirements for gain

The net protein requirements for gain for adult cows (NPg, g/d) were estimated by a linear model that takes into consideration the EBG and NEg. The BCS effect was also contemplated on the protein composition in the gain, that decreases as the BCS increases. The following equation describes the NPg:

$$NPg\ (g/d) = 307 \times EBGnp - 34 \times NEg \qquad \text{Eq. 10.12}$$

where EBGnp = non-pregnant empty body weight gain (kg) and NEg = net energy requirement for gain (Mcal/d).

An example of applying Eq. 10.12 is presented in Table 10.3. Comparison of the NPg of an adult Zebu cow and a growing heifer (350 kg) with average daily gain of 0.5 kg/d shows that the mean NPg value of a cow with BCS = 5 is about 40% lower than that of a growing Zebu heifer. This fact is explained by the variation in the gain composition, because growing heifers have a larger proportion of lean tissue gain than adult cows in average BCS. Further, Eq. 10.12 and Table 10.3 show that the larger the BCS, the smaller the proportional daily protein gain that reaches negligible values with BCS > 6.

Table 10.3 - Net protein required for weight gain of adult cows with different body condition scores and different weight gain rates

BCS	ADG, kg	EBG, kg[1.]	NPg, g/d	% of Protein in the EBG
3	0.2	0.19	26	13.7
3	0.5	0.48	60	12.6
3	0.8	0.77	92	12.0
5	0.2	0.19	20	10.4
5	0.5	0.48	43	9.0
5	0.8	0.77	64	8.3
7	0.2	0.19	15	7.9
7	0.5	0.48	30	6.3
7	0.8	0.77	42	5.5

BCS = body condition score, ADG = average daily gain, EBG = empty body gain and NPg = net protein required for weight gain; [1.]EBG = $0.963 \times ADG^{1.0151}$ (see Chapter 1).

The efficiency of use of absorbed proteins (*k*) is used to convert the net protein required for maternal tissue accumulation to metabolizable protein requirements that for adult Zebu cows is 0.27 (Gionbelli et al., work in progress). Thus the metabolizable energy required for maternal tissue weight gain (MPg, g/d) for adult Zebu cows can be calculated according to Eq. 10.13:

$$MPg\ (g/d) = NPg/0.27 \qquad \text{Eq. 10.13}$$

where NPg = net protein required for gain (g/d).

REQUIREMENTS FOR PREGNANCY

The nutritional requirements for pregnancy in the current edition of the BR-CORTE were estimated based on the only comparative slaughter experiment using pregnant and open Zebu cows (Nellore) carried out to date (Gionbelli, 2013; Gionbelli et al., 2015b). To estimate the quantities of energy and protein retained in constituents related to pregnancy, the compound pregnancy or pregnant compound concept (PREG) was adopted. The PREG concept was presented by Gionbelli et al. (2015a) and also described in Chapter 1 of the BR-CORTE. Based on the PREG, the quantities of energy and protein used to calculate the net requirements for pregnancy are those truly related to the pregnancy, which include: the gravid uterus minus the non-pregnant uterus (estimated) and the addition of the udder relative to the pregnancy. Thus the quantities of energy and protein considered as maternal tissues were those present in the carcass, internal organs, blood, head, limbs, non-pregnant udder and non-pregnant uterus. That is, the quantities of energy and protein retained in the maternal constituents or the compound pregnancy followed the same guidelines used for the weight of these compartments (described in the Chapter 1). The PREG concept did not address, however, the possible effect of pregnancy that makes maternal body components such as bones, skeletal muscular tissue, adipose tissue and internal organs vary. These variations occur as a function of the homeorhetic effect of the pregnancy (Hammond, 1947), in which peripheral tissues and organs can work to support the growth and metabolism of an organ, tissue or priority system. Such interaction is extremely difficult to model. In the study by Gionbelli et al. (2015b), however, significant evidence was not observed of the dynamic of maternal tissue deposition (variations in the gain composition of maternal tissues of pregnant and open cows).

Energy requirements for pregnancy

The equation used in the present edition of the BR-CORTE to describe the net energy and tissue growth requirements related to pregnancy in pregnant Zebu cows was created from the first derivate of a potency-type model between time pregnant and energy accumulation in PREG. Later the equation was adapted to contemplate variable calf weights at birth (CBW, in kg), so that it can be applied to herds with different phenotypes. Therefore, the net energy requirements for pregnancy (NEpreg, Mcal/d) for adult Zebu cows can be calculated by the following equation:

$$NEpreg(Mcal/d) = \frac{CBW \times 0.000000793 \times TG^{3.017}}{1000}$$

Eq. 10.14

where CBW = mean weight of the calves in the herd at calving (kg) and TG = days pregnant.

A potency-type model was used instead of a logistic model (used to estimate the gravid uterus weight in Chapter 1) to make it easier to apply the estimates because it presents non-significant differences in the estimated values. Compared to the NEpreg requirements adopted by the NRC System (BCNRM, 2016) for pregnancy with the same estimated calving weight, the requirements estimated for gestation in Zebu cows are about 30% lower (Figure 10.2).

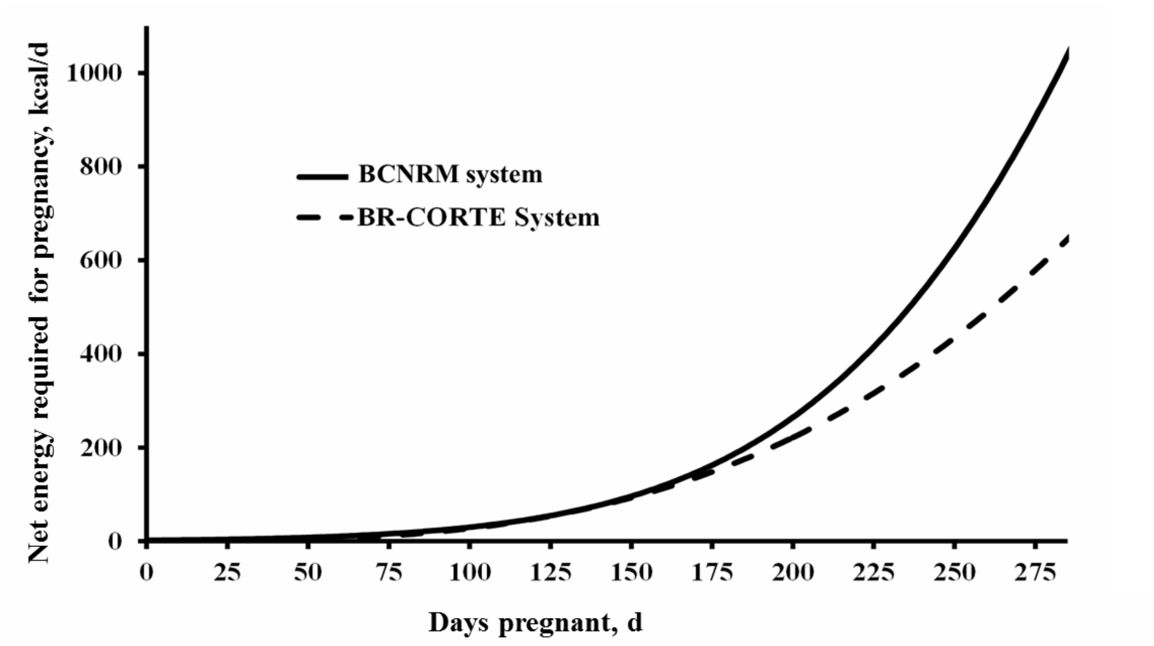

Figure 10.2 - Net energy requirements for pregnancy of an Angus-Hereford cow carrying a calf with estimated 32 kg calving weight (continuous line, BCNRM 2016) and of a Zebu cow carrying a calf with estimated 32 kg calving weight (dotted line, BR-CORTE 2016).

To convert the NEpreg requirement to the metabolizable energy requirement for pregnancy (MEpreg, Mcal/d), the NEpreg value should be divided by the efficiency of use of the metabolizable energy for pregnancy (*kpreg*), for which Gionbelli et al. (2015b) reported a value of 0.12. The *kpreg* value of 12% is fairly close to the average value of 14% obtained by Ferrell et al. (Ferrell et al., 1976c) for taurine cow gestation and also close to the value of 13% adopted by the BCNRM System (based on a mean of results from studies involving sheep and cattle). Thus MEpreg should be calculated as follows:

$$\text{MEpreg (Mcal/d)} = \text{NEpreg}/0.12 \qquad \text{Eq. 10.15}$$

where NEpreg = net energy requirement for pregnancy (Mcal/d).

Considering a Zebu cow with 500 kg BW in the last week pregnant (TG = 285) carrying a calf with 32 kg estimated calving weight, the metabolizable energy requirements for maintenance and pregnancy correspond, respectively to 12.6 and 5.4 Mcal/d. That is, at the maximum of nutritional requirements for pregnancy, the MEpreg value can reach 43% of the MEm value, considering a medium-sized cow. In small sized cows the metabolizable energy requirement for pregnancy can be greater than 50% of the maintenance requirement. Considering the last 90 d pregnancy, the average metabolizable energy requirement for pregnancy of a Zebu cow with 500 kg BW carrying a calf with 32 kg estimated calving weight is 3.5 Mcal/d, which corresponds to 28% of its maintenance requirement. That is, a 28% increase is considered necessary in the maintenance requirements for a cow of 500 kg BW to maintain a stable BCS in the last 90 d of pregnancy.

Taking as base Eq. 10.14 and Eq. 10.15, by iteration, it is observed that the MEpreg requirement becomes larger than 5% of the MEm at 140 d pregnant, when MEpreg = 0.63 Mcal/d (considering a cow with 500 kg BW carrying a calf with estimated 32 kg calving weight and MEm = 12.6 Mcal/d).

Protein requirements for pregnancy

A potency-type model was adopted in this edition of the BR-CORTE to estimate the net protein requirements for pregnancy in Zebu cows, similar to that described in Eq. 10.14 to estimate the net energy requirements for pregnancy.

$$\text{NPpreg (g/d)} = \text{CBW} \times 0.0000001773 \times \text{TG}^{2.945} \qquad \text{Eq. 10.16}$$

where CBW = mean calf birth weight of the herd (kg) and TG = days pregnant.

The Figure 10.3 presents a comparison of the NPpreg values for taurine and Zebu cows carrying calves of the same estimated calving weight. To estimate the metabolizable protein requirement for pregnancy (MPpreg, g/d), the NPpreg value should be divided by the partial efficiency of use of the protein absorbed for pregnancy, which for adult Zebu cows is 0.27 (Gionbelli et al., work in progress). Thus, the metabolizable protein requirement for pregnancy can be calculated as:

$$\text{MPpreg (Mcal/d)} = \text{NPpreg}/0.27 \qquad \text{Eq. 10.17}$$

where NPpreg = net protein requirement for pregnancy (g/d).

The metabolizable protein requirement for pregnancy calculated according to Eq. 10.16 and Eq. 10.17 for a 500 kg Zebu cow carrying a calf with 32 kg estimated calving weight, at 285 d pregnant, is 356 g/d, that corresponds to 88% of the protein requirement for maintenance of the same cow (MPm = 405 g/d). Considering the last 90 d of pregnancy, the mean MPpreg requirement for the same cow is 235 g/d, which corresponds to an average increase in protein requirement of 58%, in comparison to maintenance (not considering maternal tissue gain). These values are representative of the great increase in protein requirements as a function of days pregnant. The utero-placental and fetal metabolism rates in late pregnancy are very high (Battaglia and Meschia, 1988; Bell et al., 2005). Previous studies reported a great increase in the demand for glucose and amino acids by the placenta of ruminants during pregnancy (McNeill et al., 1997; Freetly and Ferrell, 1998, 2000). Although little is known about the breakdown of amino acids for pregnancy, it is estimated that for female ruminants in late pregnancy fed 110 to 140% of the protein requirements for pregnancy, about

80% of the digested protein passes through the gravid uterus (Bell and Ehrhardt, 1998). In female ruminants fed protein quantities close to or below the requirements for pregnancy, the levels of circulating amino acid necessary for good pregnant status are maintained by mobilizing skeletal muscle tissue (Bell and Ehrhardt, 2000). There is evidence of great maternal skeletal muscle tissue mobilization to meet the pregnancy requirements when the diet protein requirements are not met (McNeill et al., 1997).

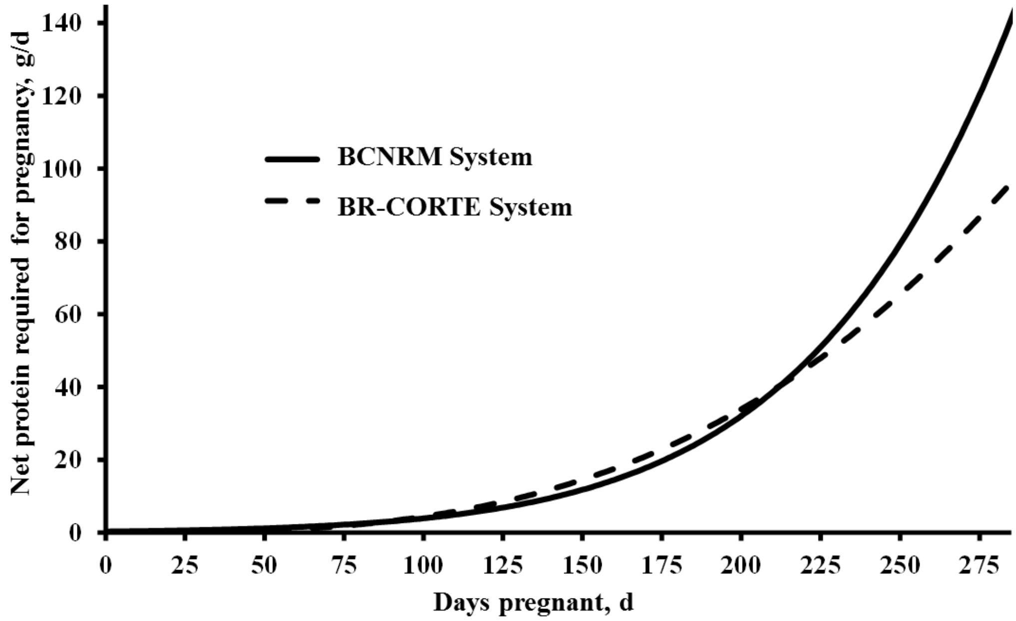

Figure 10.3 - Net protein requirements for pregnancy of an Angus-Hereford cow carrying a calf with estimated 32 kg calving weight (continuous line, BCNRM 2016) and a Nellore cow carrying a calf with estimated 32 kg calving weight (dotted line, BR-CORTE 2016).

MEETING GESTATIONAL REQUIREMENTS AND THE IMPACTS ON OFFSPRING

In addition to the discussion above, meeting, or not, the nutritional requirements for gestation can alter the development course of the offspring, impacting on its performance during postnatal life. Seasonal variation in pasture quantity and quality is a key factor reducing production efficiency. Consequently, pregnant cows reared on pasture are frequently submitted to variations in forage offer and quality especially in the dry season. To reduce this problem, some producers look for different supplementation strategies that are usually restricted to late gestation that is indicated as the main stage at which feed restriction of the dam can affect calf development, because nutrient capturing by the fetus becomes qualitatively important in the second half of the pregnancy.

However, feed restriction during early pregnancy also causes decrease in muscle and adipose tissue and calf performance, even if decreased weight and size are not observed at calving (Wu et al., 2006). This occurs as the result of specific changes in mammals during the intra-uterine development that alters development quantitatively and/or qualitatively with results that persist throughout the life of the individual. Based on this premise, studies have been carried out to understand the processes involved in tissue growth and development, since beef animal production aims to maximize their performance and muscular growth along with adequate fat deposition (Table 10.4). This understanding makes it feasible to adopt feed strategies during the different pregnancy stages that may result in increased offspring performance.

In the fetal phase, the skeletal muscle has less priority in nutrient participation compared to vital organs such as the brain and heart. In this way is, in challenging situations to the fetus during its development, the skeletal muscle tissue becomes vulnerable to the mother's nutritional deficiency. The fetal phase is critical for muscle development, because there is no increase in the number of muscle cells after calving. Muscle fiber formation is called myogenesis, a process in which multipotent mesenchymal cells are converted to muscle cells. Muscle fibers are formed from two events at different times. First, during embryo development, the primary myofibers are formed, a process that extends through the first two months of pregnancy (Russell and Oteruelo, 1981). These myofibers are used as support for later secondary myofiber formation, that occurs during the fetal phase and that contributes most to muscle mass increase in the pre-natal phase. However, most of the muscle fibers are formed between the second and eighth month of pregnancy and decrease in muscle fiber formation during this stage of fetal development causes persistent negative physiological effects in the animal during the postnatal stage (Zhu et al., 2006).

Considering that muscle cells such as adipocytes and fibroblasts are derived from the same non-differentiated mesenchymal cell pool, maternal nutrition during pregnancy has been reported as one of the key factors that affects myogenesis and consequently fetal muscle growth and development (Wu et al., 2006). Pregnancy nutrition causes modifications in the cell signaling pathway and can direct the non-differentiated mesenchymal cell pool to damage muscle cell formation by forming muscle cells, adipocytes or fibroblasts (Duarte et al., 2014).

In this way, variations in meeting the dam's nutritional requirements can be used to maximize skeletal muscle tissue development in detriment to adipose and connective tissue formation. Similarly, if it is of interest to produce animals with greater potential for body fat deposition, intra-uterine intervention can be used by gestational nutrition to maximize adipocyte development so that the animal has bigger deposition of this tissue in the postnatal phase in detriment to skeletal muscle tissue deposition.

It is pointed out that the pregnant period when the dam is not submitted to nutritional stress is crucial for programming the muscle development of the offspring. From knowledge of when muscle cell development is priority during the fetal stage will inform the time when the diet should be manipulated to maximize this tissue formation in the fetus. Similarly, if there is interest in forming more adipogenic cells to enhance fat deposition by the animal, knowledge of when there is maximum adipocyte formation will enable intervention in the development via maternal nutrition to maximize the formation of this tissue. Recent studies have shown that adipogenesis in ruminant animals starts at the same time as secondary myogenesis in midgestation (Muhlhausler et al., 2007). Thus, adopting adequate dam nutrition during pregnancy can result in a greater number of adipocytes, as a function of the increase in mesenchymal cell damage with adipogenesis, resulting in a larger quantity of intramuscular fat in the offspring.

Finally, the evidence found to date should further be emphasized that the meeting or not of the dam's nutritional requirements during pregnancy can affect the energetic metabolism of the animal during the postnatal phase. Studies have shown that fetuses of overfed ewe dams (150% NRC recommended values) presented lower activity of the main signaling pathway for the regulation of energetic metabolism in skeletal muscle tissue (known as the AMPK signaling pathway) compared to fetuses of dams receiving 100% maintenance requirements according to NRC recommendations (Zhu et al., 2008). This fact leads us to believe that, due to the possibility of perpetuating the effect throughout postnatal life, these animals could present altered growth efficiency due to changes in energy metabolism.

Table 10.4 - Selection of scientific studies published in the last five years that used ruminant animals as biological models and demonstrated alterations in fetal and/or offspring skeletal muscle development as a function of whether or not the dam's nutritional requirements were met during pregnancy

Reference	Relevant observations
Raja, JS. et al. Restricted maternal nutrition alters myogenic regulatory factor expression in satellite cells of ovine offspring, *Animal*, 2016. DOI: 10.1017/S1751731116000070	Supplying 50% of the dam maintenance requirements during gestation reduced the expressions of myogenic regulation factors in satellite cells isolated from fetal skeletal muscle tissue.
Reed, S. et al. Poor maternal nutrition inhibits muscle development in ovine offspring. *Journal of Animal Science and Biotechnology*, 2014. DOI: 10.1186/2049-1891-5-43	Supplying 60% or 140% of the dam maintenance requirements during gestation harmed offspring skeletal muscle growth
Duarte, MS. et al. Maternal overnutrition enhances mRNA expression of adipogenic markers and collagen deposition in skeletal muscle of beef cattle fetuses, *Journal of Animal Science*, 2014. DOI: 10.2527/jas.2014-7568	Supplying 140% of the dam maintenance requirements during gestation did not alter the fetal skeletal muscle development. However, the expression increased of fetal intramuscular adipogenesis markers and collagen content.
Peñagaricano, F. et al. Maternal nutrition induces gene expression changes in fetal muscle development and adipose tissues in sheep, *BMC Genomics*, 2014. DOI: 10.1186/1471-2164-15-1034	Supplying diets to dams containing different crude protein levels from mid to late gestation caused alterations in the expressions of genes involved in fetal skeletal muscle and adipose tissue development.
Yan et al. Maternal obesity downregulates microRNA let-7g expression, a possible mechanism for enhanced adipogenesis during ovine fetal skeletal muscle development, *International Journal of Obesity*, 2013. DOI: 10.1038/ ijo.2012.69	Supplying 150% of the dam´s nutritional requirements during gestation altered the expression of microRNA's favoring intramuscular fat deposition in the offspring.
Huang, Y. et al. Maternal obesity enhances collagen accumulation and cross-linking in skeletal muscle of ovine offspring, *PLoS One*, 2012. DOI: 10.1371/ journal.pone.0031691	Supplying 150% of the dam´s nutritional requirements during gestation caused greater intramuscular collagen deposition and quantity of cross-linking present in the collagen molecule.
Yan, X. Maternal obesity-impaired insulin signaling in sheep and induced lipid accumulation and fibrosis in skeletal muscle of offspring, *Biology of Reproduction*, 2011. DOI: 10.1095/biolreprod. 110.089649	Supplying 150% of the dam´s energy requirements from two months before gestation until offspring weaning diminished the signal pathway of insulin in the skeletal muscle tissue and increased fibrogenesis and intramuscular fat deposition.

DIET REQUIREMENTS AND PRACTICAL CONSIDERATIONS FOR GESTATIONAL NUTRIENT REQUIREMENTS

Diet energy requirements for open and pregnant cows

The total metabolizable energy requirements (MEtotal, Mcal/d) for adult Zebu pregnant and open cows are represented by the sum of the requirements for maintenance, maternal tissue gain and gestation, as follows:

Open cows

$$\text{MEtotal} = \text{MEm} + \text{MEg} \quad \text{Eq. 10.18}$$

Pregnant cows

$$\text{MEtotal} = \text{MEm} + \text{MEg} + \text{MEpreg} \quad \text{Eq. 10.19}$$

where MEm = metabolizable energy requirement for maintenance (Mcal/d), MEg = metabolizable energy requirement for maternal tissue gain (Mcal/d) and MEpreg = metabolizable energy requirement for pregnancy (Mcal/d).

To convert the metabolizable energy requirements to the digestible energy requirements for adult Zebu cows, when the energy concentration of the diet (or only the forage, for pasture-raised cows without supplementation) is known (Mcal DE/kg or TDN) the first three equations below can be used (Eq. 10.20, Eq. 10.21, or Eq. 10.22). When the energetic concentration of the diet is not known, Eq. 10.23 should be used:

$$[\text{ME}] = 0.9147 \times [\text{DE}] - 0.2227 \quad \text{Eq. 10.20}$$

$$[DE] = \frac{0.2227 + [ME]}{0.9147}$$
Eq. 10.21

$$ME / DE = 0.65 + 0.44 \times TDN - 0.24 \times TDN^2$$
Eq. 10.22

$$DE = ME / 0.82$$
Eq. 10.23

where [ME] = metabolizable energy concentration (Mcal/kg), [DE] = digestible energy concentration (Mcal/kg), ME = metabolizable energy (Mcal/d), DE = digestible energy (Mcal/d) and TDN = total digestible nutrients (in centesimal scale, from 0 to 1).

Equations Eq. 10.20 and Eq. 10.21 are derived from the ME and DE ratio obtained in diets of pregnant and open adult Zebu cows (Figure 10.4). Eq. 10.22 is a variation on the previous equations, considering 1 kg de TDN = 4.4 Mcal of DE. Eq. 10.23 represents the standard value of the DE to ME conversion efficiency used historically by the feeding systems (BCNRM and BR-CORTE). For adult Zebu cows, the coefficient of 0.82 represents, according to Eq. 10.23, a diet with 55% TDN. The ratio presented in Figure 10.4 does not differ greatly from that obtained by Galyean et al. (2016) for growing and finishing *Bos taurus* cattle (ME = 0.9611 × DE – 0.2999).

To convert the total digestible energy requirements to diet energy requirements, represented by TDN, the DEtotal value should be divided by 4.4, considering the relationship 1 kg TDN = 4.4 Mcal of DE.

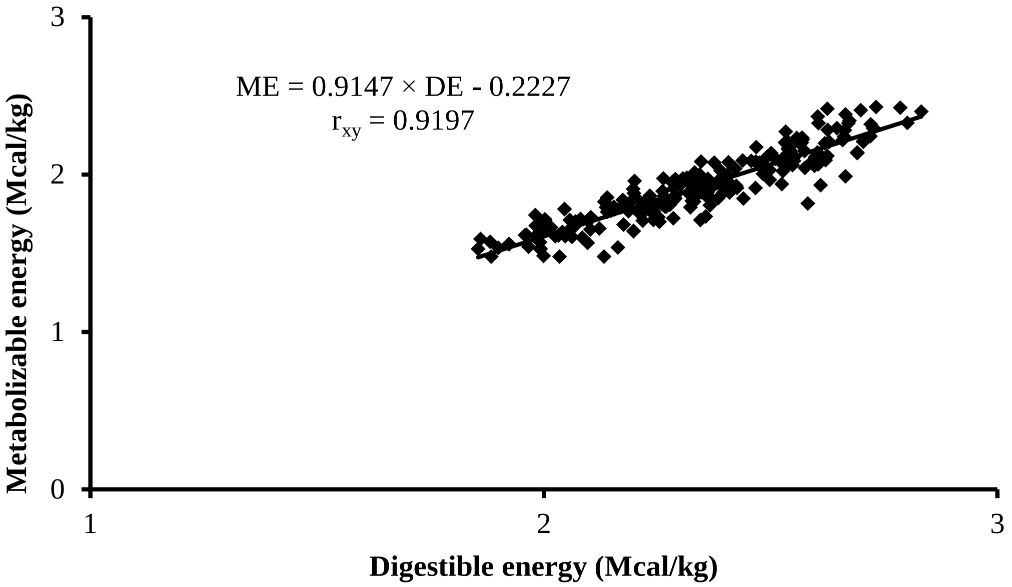

Figure 10.4 - Metabolizable energy and digestible energy ratio in adult Zebu cows (Gionbelli et al., work in progress).

Protein diet requirements for pregnant and open cows

The total metabolizable protein requirements (MPtotal, g/d) for adult Zebu pregnant or open cows are represented by the sum of the requirements for maintenance, maternal tissue gain and pregnancy, as follows:

Open cows
$$MPtotal = MPm + MPg$$
Eq. 10.24

Pregnant cows
$$MPtotal = MPm + MPg + MPpreg$$
Eq. 10.25

where MPm = metabolizable protein requirement for maintenance (g/d), MPg = metabolizable protein requirement for maternal tissue gain (g/d) and MPpreg = metabolizable protein requirement for pregnancy (g/d).

The same procedures described for growing and finishing animals are used to convert the total metabolizable protein requirements to rumen degradable protein

(RDP), rumen undegradable protein (RUP) and total crude protein (CP) requirements, (see Chapter 8). In this sense, the crude protein requirements are represented by the sum of the RDP and RUP requirements.

In the present edition of the BR-CORTE, the RDP diet requirements are considered equal to the daily microbial crude protein production (MCP), because the estimates of N that returns to the rumen by N recycling could compensate quantitatively the inefficiency of degradable protein conversion in the rumen to MCP, estimated at 10% in the previous editions of the BR-CORTE. Thus we have that RDP = MCP. Daily MCP production is estimated by the equation below (presented in chapter 3 of this edition of the BR-CORTE):

$$MCP\ (g/d) = -53.07 + 304.9 \times CPI + 90.8 \times TDNI - 3.13 \times TDNI^2 \quad \text{Eq. 10.26}$$

where: CPI = crude protein intake (kg/d) and TDNI = TDN intake (kg/d). In this equation, the TDNI should be the diet requirement of TDN in (kg/d) calculated as described in the previous item.

The RUP (kg/d) diet requirements for adult Zebu open and pregnant cows can be calculated by the equation below (see Chapter 8):

$$RUP\ (g/d) = (MPtotal - (MCP \times 0.64))/0.80 \quad \text{Eq. 10.27}$$

where MPtotal = total metabolizable protein requirement (g/d) and MCP = daily microbial crude protein production (g/d).

Practical considerations for nutritional requirements for pregnancy

Based on the models used in this chapter to estimate the energy and protein requirements for pregnancy, it was observed that the quantities required to support growth of the gravid uterus constituents during early gestation are small. Quantitatively, the metabolizable energy and protein requirements for pregnancy represent more than 5% of the metabolizable energy and protein requirements for maintenance starting at 141 and 111 d of gestation, respectively (considering a cow with 500 kg BW carrying a calf with estimated 32 kg calving weight). To facilitate the practical application of the requirements proposed here for pregnancy, it is important to consider the requirements for pregnancy starting at the time when they represent a significant percentage of the cow diet. Thus, for the present edition of the BR-CORTE, it was considered that the requirements for pregnancy are significant from the practical point of view after 135 d of gestation (4.5 months pregnant) when the energy and protein requirements represent, on average, a 7.3% increase over the maintenance requirements (4.5% for energy and 10% for protein). This point was chosen because it is the time when the energy or protein requirements come to represent more than 10% of the maintenance requirements. Before 135 d pregnant, the requirements for pregnancy can be considered insignificant and do not need to be considered. Thus the protein and energy requirements for gestation are considered significant in the 135 d of gestation (considering a 290 d pregnant in Zebu).

The requirements for pregnancy and how they should be considered in the nutritional programs applied to pregnant cows vary throughout pregnancy. It is known that in practice it is not feasible to adjust the diet of pregnant cows in short periods of time (weekly, for example). Thus a step-type scheme is proposed to meet the gestation requirements, containing three stages, divided according to the variations in the nutritional requirements for pregnancy. These three stages, called early, mid and late pregnancy have distinct durations and are best visualized in Figure 10.5 and Table 10.5.

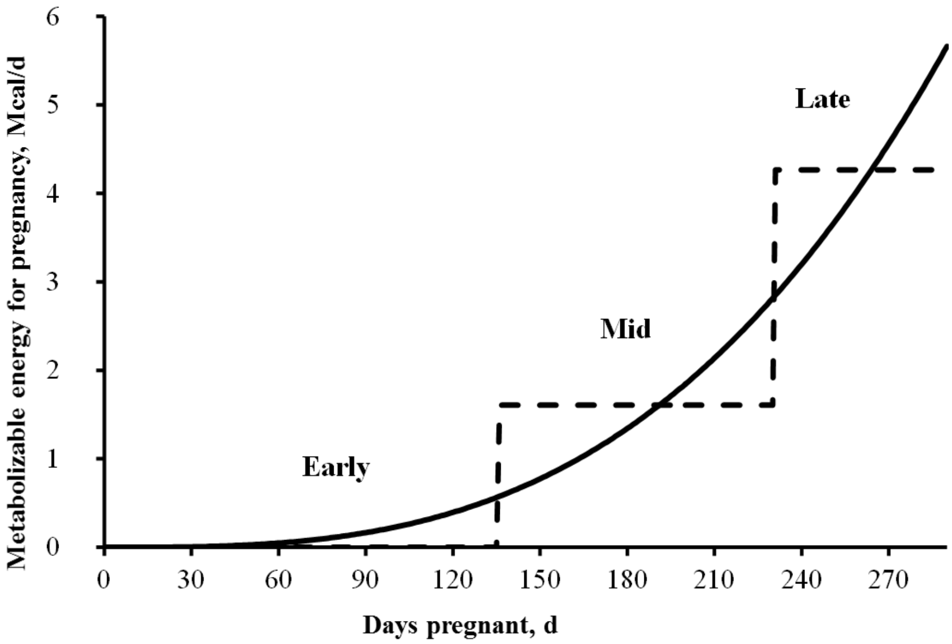

Figure 10.4 - Metabolizable energy requirements for pregnancy of an adult Zebu cow (500 kg BW carrying a calf with estimated 32 kg calving weight) divided into three pregnant periods (early, mid and late). The continuous line represents the requirements calculated daily and the dotted line represents the mean requirements to be considered in each period.

Table 10.5 - Description and duration of the gestation periods for practical application of the nutritional requirements for pregnancy of adult Zebu cows

Pregnant period		Pregnancy requirements (equivalents)[1.]
Name	Duration (d)	
Early	135 (0 to 135th)	-
Mid	95 (136 to 230th)	191 d pregnant
Late	60 (231 to 290th)	264 d pregnant

[1.]Up to 135 d pregnant: pregnancy requirements are considered not significant. In mid gestation (136 to 230 d), the mean requirements are equivalent to the requirements at 191 d pregnant. In late pregnancy (231 to 290 d), the mean requirements are equivalent to the requirements at 264 d pregnant. That is, the pregnancy requirements in mid and late pregnancy should be calculated using, respectively, 191 and 264 d pregnant and the models described in this Chapter.

According to the production system and technical recommendation, a larger number of steps can be used to elaborate nutritional programs for pregnant cows. The steps presented above are adopted in this edition of the BR-CORTE.

Zebu cow nutritional requirements over a productive cycle (period between two calvings) can be better understood according to Table 10.6. This means that, in the case of a cow with a 12-month calving interval from calving to weaning, the nutritional requirement should be calculated according to Chapter 11 of this edition of the BR-CORTE (nutritional requirements for lactating Zebu cows and their calves). After weaning, the nutritional requirements for this cow should be calculated according to the requirements for midgestation, because with a 12-month calving interval, the cow would have conceived at 75 d of lactation and at weaning will be with 135 d pregnant. If the calving interval is 14 months, there will be a period (60 d) of the productive cycle when the cow will not be lactating and in early pregnancy, when the requirements for gestation are not significant. In this case, during this period, the total requirements of such a cow should be calculated as maintenance requirements + maternal gain tissue requirements, as described in this Chapter.

Table 10.6 - How to calculate the nutritional requirements for Zebu cows according to the stage of the productive cycle when the calving interval is 12, 14, 16 or 18 months

Calving interval, months (d)	Productive cycle phase (duration and justification)			
	Lactation	Non-lactating, open or early pregnancy	Midgestation	Late pregnancy
12 (365)	210 d (calving to weaning)	0 d, because it will have been conceived at 75 d lactation and at weaning it will be at 135 d pregnant	95 d (136 to 230th d pregnant)	60 d (231st d pregnant until calving)
14 (425)	210 d (calving to weaning)	60 d, because it will have conceived at 135 d lactation and it will be 75 d pregnant at weaning	95 d (136 to 230th d pregnant)	60 d (231st d pregnant until calving)
16 (485)	210 d (calving to weaning)	120 d, because it will have conceived at 195 d lactation and it will be 15 d pregnant at weaning	95 d (136 to 230th d pregnant)	60 d (231st d pregnant until calving)
18 (545)	210 d (calving to weaning)	180 d, because it will have conceived at 45 after weaning	95 d (136 to 230th d pregnant)	60 d (231st d pregnant until calving)
How to calculate the nutritional requirements?	**Requirements for lactating cows (Chapter 11)**	**Requirements for open cows (maintenance+ maternal tissue gain)**	**Requirements for cows at midgestation (maintenance+ maternal tissue gain + requirements for 191 d pregnant)**	**Requirements for cows at late pregnancy (maintenance+ maternal tissue gain + requirements for hundred 264 d pregnant)**

Based on Table 10.6 the duration of the period when the cow requirements should be calculated for non-lactating, open or early pregnancy (maintenance + maternal tissue gain) should be estimated based on the calving to conception interval and during lactation (age at weaning adopted for the herd) as follows:

$$PX = 135 + CCI - LACT \quad \text{Eq. 10.28}$$

where PX = duration of the period (d) when the requirements of the cow should be considered equal to the requirements of maintenance + maternal tissue gain (non-lactating and open or with non-specific requirements for pregnancy), CCI = calving- to-conception interval (d) and LACT = duration of the lactation (d).

Taking as base Eq. 10.28, a cow that conceives at 100 d after calving (CCI = 100), in a production system with calf weaning age of seven months (LACT = 210), will have a 25 d of PX (PX = 135 + 100 – 210). A cow that conceives at 80 d after calving (CCI = 80), in a production system that adopts early weaning with three-month-old calves (LACT = 90), will have a 125-d PX (PX = 135 + 80 – 90). Thus, in the case of this last example, after weaning, the cow should receive a diet that meets its requirements for maintenance + maternal tissue gain for a period of 125 d after weaning and it should then receive a diet that meets the maintenance requirements, maternal gains and requirements for the midgestation.

Mineral requirements for pregnant and open cows

Data on the mineral requirements for pregnancy in adult Zebu cows are not yet available for this edition of the BR-CORTE. Thus, it is suggested that the estimates and mineral requirements for maintenance of beef Zebu heifers presented in Chapter 9 of this edition of the BR-CORTE should be adopted. For pregnant cows, an increase of 12 and 33% in the mineral requirements is suggested during mid- and late pregnancy. These values are based on the mean increase in energy requirements that occurs as a function of pregnancy. Thus the mineral requirements for open and pregnant Zebu cows can be calculated according to Table 10.7.

Table 10.7 - Suggestion for calculating mineral nutritional requirements for adult Zebu open and pregnant cows

Category	Mineral requirements
Open cows and up to 135 d pregnant	Maintenance
Midgestation (136 to 230 d pregnant)	Maintenance × 1.12
Late pregnancy (231 d pregnant to calving)	Maintenance × 1.33

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