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Adjusting cattle body weight to physiological and feeding conditions

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The result of weighting cattle does not represent the true weight of its body. Approximately 10–20% of the body weight of cattle as measured by a scale is the gastrointestinal tract content. This proportion can vary depending on whether the animal is fed or fasting. The ratio between the scale's weight and the true body weight of an animal can also vary as a function of age. In females, these ratios also vary because of the physiological stage (non-pregnant, lactation, and pregnant). To measure growth and performance or to estimate nutrient requirements of beef cattle, the true weight of their constituents must be known exactly. This chapter describes mathematical models developed from experiments carried out to estimate, with the maximum possible accuracy, the body weight of a cattle as a function of its feeding state and physiological conditions.

INTRODUCTION

The BR-CORTE system and all the other beef cattle feeding systems currently in use (NRC, ARC, AFRC, CSIRO, INRA, etc.) are the result of extensive and painstaking research. In these situations, the animals are weighed rigorously and precisely, and variations in weight are normally taken by weighing after a period of fasting or by weighing the body constituents after slaughter.

The aim of weighing after fasting is to have a mean closer to the true body weight of the animal (empty body weight). Weighing after fasting improves experimental precision because there is a reduction in the proportion of the observed weight that results from filling (gastrointestinal tract contents). Variations in gastrointestinal tract contents (GIT) are considered to be the highest source of error when measuring body weight gain in ruminants (Lofgreen et al., 1962).

Estimates of nutrient requirements from the BR-CORTE system are obtained mostly by meta-analyses through comparative slaughter experiments. These cases provide the true weight of the animal, because immediately after slaughter, the GIT is washed and weighed empty, then joined to other portions of the animal body to form an exact measurement of the mass of an animal, the empty body weight (EBW). Because it represents exactly the animal mass, the EBW is used as a base to calculate most of the nutrient requirements in the BR-CORTE and also in other feeding systems. However, fasting animals are rarely weighed in beef cattle production systems in Brazil. Methods are necessary therefore to accurately estimate the shrunk and empty body weights of the animals as a function of their body weights collected in field conditions.

Variation in the ratios among fed, fasting and empty body weight can be affected by sex, genetic group and animal weight. Little attention has been paid to these ratios and to the factors that act on them in previous editions of the feeding systems in use around the world.

This chapter was written aiming to establish the weighing ratios in beef cattle and also the definitions of weighing, so that the necessary measurement can be accessed correctly from a measurement obtained in the field to estimate the nutrient requirements of the animal.

DEFINITIONS OF WEIGHING IN RESEARCH AND IN FIELD CONDITIONS

Although, usually people refer to the weight of an animal, in reality, its mass is being considered. Mass and weight are different physical values: mass is an inert value while weight is a vector value. Mass is the quantity of matter present in a body and measured on scales, whose standard unit in the International System of Units is kilogram (kg). Weight is the product of the mass of a body and the local gravity acceleration, which depends on the attraction that one body exercises over the others, as given by gravity acceleration, whose standard unit in the International System is Newton (N). However, on the Earth's surface, the force of gravity is constant and therefore the mass-weight ratios do not usually vary. Thus, although the weight of an animal is referred to, mass is being considered. Although this is a conceptual error, it does not alter the practical use of the concept of mass. Therefore, when there is a reference to an animal with a weight of 300 kg, what is truly considered is a mass of 300 kg, or a true weight of 300 force kilograms or approximately 3000 Newtons.

The simplest measurement used to refer to the mass of an animal is the result of weighing the animal while in normal feeding conditions, carried out at any time of the day. This measurement is normally referred to as live weight or body weight (BW), although there are no practical differences between both. The term BW is adopted in this system. This measurement represents the weight of the animal in fed status (fed weight), which is also called "full weight". Although in the field there is no determined time to take this measurement, under research conditions, so as to establish standardization, and searching for the least possible variability, the animal is always weighed in the morning, between 05:00 and 07:00 a.m.

Although BW is the weighing measurement used most in practice, in research, weighing in fasting is preferred to reduce the fill effect and improve the precision of the measurements. Weighing the animals after a defined period of fasting from solids reduces the percentage of measurements taken that represents GIT fill. There are suggestions to weigh animals after fasting varying from 12 to 16 hours. In all the studies that form the base of the BR-CORTE System, weighing in fasting is carried out after 16 hours fasting from solids, and the measurement is given the name of shrunk body weight (SBW). In experiments to compare weight gain obtained by animals submitted to different treatments, the SBW has been considered the most adequate measurement to be taken at the start and end of the experiment. It is used to calculate the shrunk average daily gain (SADG) as the difference between the final and initial weighing in fasting, divided by the number of days of assessment. However, this measurement was always named average daily gain (ADG), even when taken from the differences between weightings during fasting. Unlike the SADG, the ADG represents, in theory, the average daily gain calculated based on the difference of two weightings without fasting (BW). Although they are theoretically different, differences have not been expressed between the two measurements (SADG and ADG). In practice, the differences are negligible (0.56%, based on the database of the BR-CORTE System), so that using the ADG is not problematic when taken from different weightings in fasting or from different weightings in fed animals. However, it should be noted that the ADG measurement should be obtained from the difference between two weightings in the same fed status. That is, if the initial weighing was taken in fasting, the final weighing should also be taken in fasting.

Although the SBW represents the mass of an animal more accurately than the BW, there is still a considerable fraction of GIT content in the SBW measurement. The accurate measurement of body mass can only be obtained by weighing the animal completely free of GIT. As it is impossible to take such a measurement with live animals, the empty body weight (EBW) value is only obtained after slaughtering the animal, when the GIT is washed and its weight added to the other body constituents. Most of the values for cattle nutritional requirements are calculated from the EBW, because EBW represents the true body mass of the animal. The true accumulation of body weight obtained after a determined assessment period, divided by the number of days of assessment, is named the empty body gain (EBG).

Estimates of energy nutritional requirements adopted by the cattle feeding systems are expressed in metabolic size unit. Metabolic size is a concept that was created to compare the metabolic rates of animals with different body sizes (Kleiber, 1932, 1947; Brody, 1945; Kleiber, 1965; White and Seymour, 2005). It is based on the observation that the surface area of two bodies with similar shape and density is proportional to ¾ of their weight. Consequently, the metabolic rates of these different bodies are proportional to their weights, raised to the power of 0.75 ($BW^{0.75}$), a value obtained from comparing the heat production in fasting of adult animals from different species (Brody, 1945). In the BR-CORTE System, the metabolic size concept is used to express energy requirements for maintenance, where the necessary expenditure for maintenance is expressed in units of metabolic empty body weight ($EBW^{0.75}$).

Another weight relationship used by the BR-CORTE System is the equivalent weight or equivalent empty body weight (EQEBW). The EQEBW is a measurement based on the estimated weight at animal maturity. Weight at maturity represents the weight at which muscle mass growth practically stops, and from there onwards there is significant growth only through energy reserve accumulation, which can also be determined from body fat content. The EQEBW is, therefore, a ratio used to describe animals from different sexes or genetic groups on the same scale of proportion of weight at maturity. It is used to simplify the expression of the energy requirements for growth, because animals of different sexes or genetic groups reach maturity at different EBW.

The Table 1.1 shows a summary of the abbreviations, practical and theoretical definitions of the different ways of expressing animal mass used in the BR-CORTE System. Suggested ways to estimate the ratios between the units presented in Table 1.1 are described in the following items.

Table 1.1 - Weighing definitions used in the BR-CORTE system

Abbreviation	**Definitions found**	**True definition**	**How to obtain**
BW	Body weight, live weight, fed weight	Animal mass with feed and water permanently available (kg)	Weigh the animal without fasting from solids or liquids, between 05:00 and 07:00 a.m.
SBW	Shrunk body weight, shrunk weight	Animal mass measured after 16 hours fasting from solids (kg)	Weigh the animal in the morning, after 16 hours fasting from solids
EBW	Empty body weight	Animal mass without the gastrointestinal tract content or true mass of the body constituents of the animal (kg)	Immediately after slaughter, wash the gastrointestinal tract and weigh empty. Add the weight of the empty gastrointestinal tract to the other body constituents (hide, blood, carcass, viscera, head, limbs, etc. …)
$EBW^{0.75}$	Metabolic empty body weight	Animal mass without gastrointestinal tract contents raised to the power of 0.75 or empty metabolic mass (kg)	Raise the EBW to the power of 0.75
EQEBW	Equivalent empty body weight	Animal mass without the gastrointestinal tract contents proportional to the weight at maturity of a reference animal	Divide the EBW by the weight at maturity of the respective sex/genetic group and multiply by the reference weight

DATABASE FOR WEIGHT ADJUSTMENTS

A database containing information from 40 experiments carried out in Brazil during the period from 1991 to 2016 was used to establish the weight ratios (BW to EBW and ADG to EBG) for growing and finishing animals in the BR-CORTE System (Table 1.2). A histogram of the frequency distribution of the SBW variable is shown in Figure 1.1.

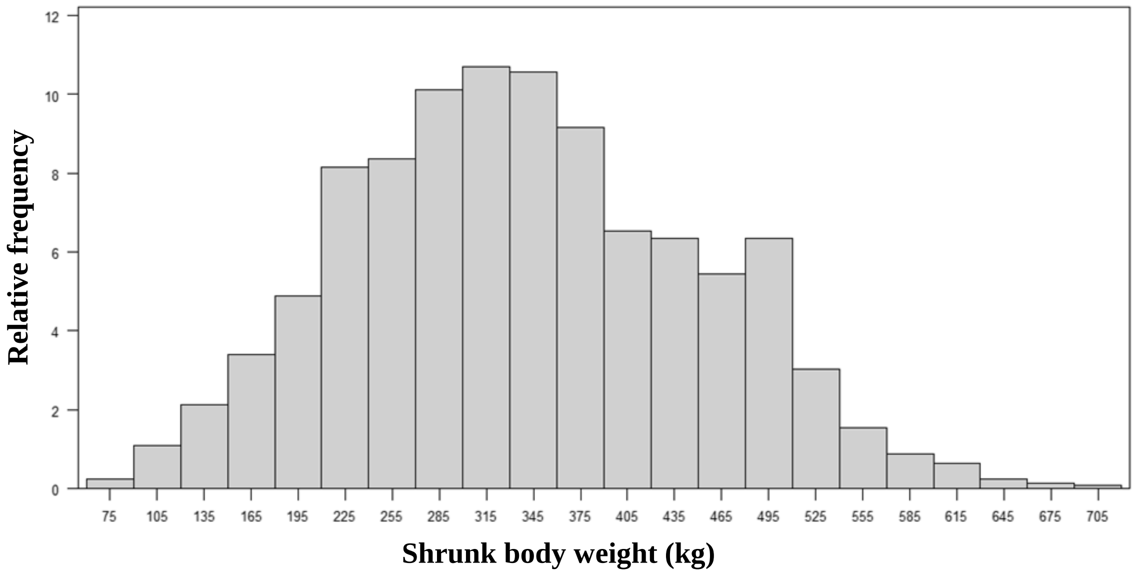

Figure 1.1 **-** Histogram of the frequency distribution of the SBW variable.

Table 1.2 - Description of the database used to establish the weight ratios in the BR-CORTE system

Item[1]	Variable								
	BW (kg)	SBW (kg)	EBW (kg)	ADG (kg/d)	SADG (kg/d)	EBG (kg/d)	SBW/BW	EBW/SBW	EBG/ SADG
N	409	2,855	1,514	129	1,020	1,020	409	1,514	953
Minimum	81.0	74	63	-0.24	-0.54	-0.55	0.90	0.76	0.71
Mean	381	340	290	0.77	0.91	0.88	0.98	0.88	0.96
Median	388	333	285	0.89	0.94	0.90	0.98	0.88	0.96
Maximum	710	701	600	1.61	2.66	2.74	1.01	0.97	0.98
SD	144	111	93.0	0.44	0.52	0.52	0.02	0.04	0.21
CV (%)	38.0	33.0	32.0	58.0	57.0	59.0	2.00	5.00	22.0

[1]SD = standard deviation; CV = coefficient of variation.

WEIGHT RATIOS

After assessing adherence to the normal distribution, the first step to check the weight ratios to use in the BR-CORTE System was to assess the fit of models that best describe these statistical and biological relationships. In the previous edition of BR-CORTE (Valadares Filho et al., 2010) linear relationships between EBW and SBW and between EBG and SADG had been established and presented in the energy requirements chapter (Marcondes et al., 2010). The BW:SBW ratio was not estimated in the BR-CORTE in 2010, and the fixed ratio as suggested (SBW = BW × 0.96) by the NRC (2000) was adopted.

The use of linear weight relationships implies suggesting that the proportions of weight lost in fasting in the BW and gastrointestinal tract content in the SBW are constant and do not vary with increase in animal weight. There is evidence, however, that these relationships are not linear

(Gionbelli et al., 2015). Therefore, the fit was assessed using two mathematical model structures (linear and non-linear) for the relationships between weights, as showed in Table 1.3. The structures of the model presented in Table 1.3 were compared by the Akaike Information Criterion (AIC) (Akaike, 1974). For all the relationships assessed, the use of the non-linear model, although with a greater number of parameters, presented the lowest AIC value, indicating best fit. Analysis of the relationship between predicted and observed values was carried out by fitting simple linear regression (predicted values = X, observed values = Y) to assess the quality/lack of fit of the nonlinear models to the three ratios. In this case, the hypothesis that $\beta_0 = 0$ and $\beta_1 = 1$ was accepted ($P \geq 0.89$). The probability of best fit of the non-linear model in relation to the linear model was estimated by calculating the evidence ratio for the absolute difference between the AIC values estimated for the fit of the two model structures (Motulsky and Christopoulos, 2003). The result of the evidence ratio (or relative probability) of the AIC favorable to the nonlinear model is also shown in Table 1.3 and can be interpreted as the probability that the nonlinear model presents a better fit than the linear model.

In addition to better statistical fit, applying non-linear models to the weight ratios shown in Table 1.3 is also more adequate from the biological point of view, because it considers that the weight proportions and gain rate vary as the animal varies in weight. For the EBW:SBW ratio, for example, it is suggested that the proportion of the SBW that is represented by GIT fill decreases with the increase in size of the animal. Then the effects of feeding system (pasture × feedlot), sex and genetic group on the weight ratios were tested, as described in the following items.

Table 1.3 - Weight ratios, structures of models assessed to describe the weight ratios and value of the Akaike Information Criterion evidence ratio favorable to use of the non-linear model

Ratio	Linear model	Non-linear model	AIC evidence ratio favorable to the non-linear model
$SBW = f(BW)$	$SBW = a \times BW$	$SBW = a \times BW^b$	89%
$EBW = f(SBW)$	$EBW = a \times SBW$	$EBW = a \times SBW^b$	80%
$EBG = f(ADG)$	$EBG = a \times ADG$	$EBG = a \times ADG^b$	100%

Estimating shrunk body weight (SBW) from body weight (BW)

Although weighing after a 12 to 16 hour fasting from solids presents a lower value than weighing a fed animal, the need to establish a relationship between SBW and BW for Zebu cattle and their crosses has only recently been observed. Although the difference between BW and SBW is not greater than 5%, it is extremely important to consider it, because it represents the first connection between measurements obtained in experiments (SBW) and measurements taken in the day-to-day of the productive systems (BW).

Since 2010, BW and SBW data were collected from the same animals in a large part of the experiments carried out to make the BR-CORTE database. However, this measurement requires weightings on different days. Then, the animals were weighed in fed status on one day (BW); solid food was removed 16 hours before the next weighing that was performed at exactly the same time on the next day (SBW). In this way, 409 BW and SBW measurements were obtained for the same animals, with a one-day interval. The value of one day of ADG obtained in the assessment period in which these measurements were taken was discounted from the SBW value to correctly establish the ratio, because these measurements had been taken with one day of difference.

Since measurements of the SBW:BW ratio began recently, only data from Zebu and dairy crossbred genetic groups were available at the time of writing this chapter. The number of experiments carried out with animals of different sexes was also sufficient to assess the effect of sex on the meta-analysis carried out. Therefore, only the test of the possible difference between Zebu and dairy crossbred animals kept in feedlot, regardless of sex, was considered.

Non-linear models to estimate the SBW as a function of the BW were fitted to the data from Zebu and dairy crossbred by the NLMIXED procedure of SAS considering effect of repeated measures in time when the BW and SBW measurements were taken more than once on the same animal. An *F* ratio was calculated to test whether the estimate of specific parameters for each genetic group significantly improved the fit of the data in relation to the use of single parameters for both genetic groups. The P value for F-distribution applied to the calculated ratio showed there was statistical gain for the fit of different parameters for Zebu and dairy crossbred compared to the use of single parameters (P=0.007). Then the effects of the genetic group were tested on each of the parameters of the nonlinear model using the ESTIMATE function of the NLIN procedure of SAS. Differences were observed between Zebu and dairy crossbred for the parameters *a* (P<0.003) and *b* (P<0.004). Two models were thus generated with independent parameters for Zebu and dairy crossbred, as follows:

Zebu cattle:

$$SBW = 0.8800 \times BW^{1.0175}$$

Eq. 1.1

Dairy crossbred cattle:

$$SBW = 0.9664 \times BW^{1.0017}$$

Eq. 1.2

where SBW = shrunk body weight and BW = body weight.

An example of the use of the equations above to estimate the SBW of animals from different genetic groups from different BW values is shown in Table 1.4. It was observed for Zebu animals that the proportional weight loss as a function of 16 hours fasting from solids was greater when the size of the animal was smaller and was close to that attributed by the NRC (2000) only in light animals (approximate 150 kg). Although they are data from growing and finishing animals, the variation in the ratio as a function of weight increase is similar to that observed for adult Zebu cows (Gionbelli et al., 2015). In dairy crossbred, the mean ratio between SBW and BW is practically linear and greater than that attributed by the NRC (2000).

Table 1.4 - Application of Eq. 1.1 and Eq. 1.2 to estimate shrunk body weight from body weight

BW (kg)	SBW (kg)		SBW/BW		Difference in Weigh (kg)		Decrease in BW (%)	
	Zebu	Dairy Crossbred	Zebu	Dairy Crossbred	Zebu	Dairy crossbred	Zebu	Dairy crossbred
150	144	146	0.961	0.975	5.9	3.8	3.9	2.5
300	292	293	0.972	0.976	8.3	7.3	2.8	2.4
450	441	439	0.979	0.976	9.3	10.6	2.1	2.4
600	591	586	0.984	0.977	9.5	13.8	1.6	2.3

For beef crossbred, although it was not possible to establish the ratio based on real data, the use of Eq. 1.2 (Dairy crossbred) is suggested because the BW-GIT fill ratios of these animals are more similar to those observed for crossbred dairy cattle as opposed to Zebu (Lana et al., 1992). It is also considered more appropriate to use Eq. 1.2 than the fixed ratio adopted by the NRC (2000) (0.96) because it was developed from animals raised under tropical conditions.

For animals reared on pasture, although the equations here proposed were generated from animals on feedlot, it is considered more prudent to convert from BW to SBW using Eq. 1.1 (the experiments with animals on pasture that are part of the BR-CORTE were carried out mostly with Zebu animals) than to not calculate or use the fixed 0.96 ratio. The EBW estimate for animals on pasture is obtained from SBW data of experiments carried out on pasture, where the animals were shut in a paddock with fasting from solids until SBW was measured, always in the morning.

Estimating empty body weight (EBW) from shrunk body weight (SBW)

The BR-CORTE System database contains abundant data (n=1514, Table 1.2) to establish the relationship between EBW and SBW. Therefore, the effects of feeding system, sex and genetic group could be tested on the parameters of the linear model fitted to the ratio. The *F* test showed there was statistical improvement (P<0.04) in the fit of the models separated, according to the various classes of the tested fixed effects (feeding system, sex and genetic group).

Data from animals raised on pasture were contrasted with data from animals of the same genetic groups (Zebu and Dairy crossbred cattle) and sexes (steers and bulls) raised on a feedlot by meta-analysis considering only the fixed effect of the feeding system and random effects of sex, genetic group and experiment (number of experiments with variation in sex and genetic group did not allow comparison to fit the parameters for these effects). Feeding system influenced both parameters of the non-linear model (P<0.01). A non-linear model was then fitted to establish the relationship between EBW and SBW of animals on pasture, as follows:

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

Eq. 1.3

where EBW = empty body weight and SBW = shrunk body weight.

The Eq. 1.3 shows that the EBW-SBW ratio is practically linear in animals raised on pasture. Although the number of experiments has increased, the ratio is also fairly close to that proposed in the previous edition of the BR-CORTE (EBW = 0.863 × SBW).

For animals in a feedlot, a significant effect was observed for the sex and genetic group interaction on the parameters of the non-linear model (P<0.003). However, differences were not observed between Dairy and Beef crossbred for parameters *a* (P>0.70) and *b* (P>0.63). Because of this, independent models were fitted considering the differences among bulls, steers and heifers, and between Zebu animals and their crosses (Dairy or Beef), as follows:

Bulls	Zebu	$EBW = 0.8126 \times SBW^{1.0134}$	Eq. 1.4
	Crossbred	$EBW = 0.7248 \times SBW^{1.0314}$	Eq. 1.5
Steers	Zebu	$EBW = 0.6241 \times SBW^{1.0608}$	Eq. 1.6
	Crossbred	$EBW = 0.6586 \times SBW^{1.0499}$	Eq. 1.7
Heifers	Zebu	$EBW = 0.6110 \times SBW^{1.0667}$	Eq. 1.8
	Crossbred	$EBW = 0.6314 \times SBW^{1.0602}$	Eq. 1.9

where EBW = empty body weight and SBW = shrunk body weight.

In the previous edition of the BR-CORTE, a single linear ratio had been proposed to establish the ratio between EBW and SBW for feedlot animals (EBW = 0.895 × SBW). Considering the estimates of Eq. 1.4 to Eq. 1.9, and animals from 150 to 600 kg SBW, it was observed that the EBW:SBW ratio in Zebu and their crosses on feedlot ranged from 84.6 to 93.6%, with a mean of 89.7% (0.897), a similar value to that adopted for animals on feedlot in the previous edition of the BR-CORTE. Although this suggests that the EBW:SBW ratio may vary from 85–95%, the NRC (2000) suggests the use of a fixed ratio of 0.891. However, the use of multiple equations with effects of sex and genetic group to estimate EBW, as proposed in the current edition, improves the accuracy and precision of the EBW estimates. Table 1.5 shows an example of applying Eq.1.3 (pasture) and Eq. 1.4 (feedlot) to estimate EBW for Zebu bulls. An example of the variability in the EBW and SBW ratios obtained from Eq. 1.4 to Eq. 1.9 is shown in Table 1.6.

Table 1.5 - Example of applying Eq. 1.3 and Eq.1.4 to estimate empty body weight from shrunk body weight of Zebu bulls on pasture and feedlot

BW (kg)	SBW (kg)	Pasture		Feedlot	
		EBW (kg)	EBW/SBW	EBW (kg)	EBW/SBW
150	144	123	0.852	125	0.869
300	292	248	0.852	256	0.877
450	441	375	0.852	389	0.882
600	591	503	0.852	523	0.885

Table 1.6 - Ratio between empty body weight and shrunk body weight (EBW/SBW) in Zebu and their crosses, on feedlot, at different weights, estimated from Eq. 1.4 to Eq.1.9

SBW	Bulls		Steers		Heifers	
(kg)	Zebu	Crossbred	Zebu	Crossbred	Zebu	Crossbred
150	0.869	0.848	0.846	0.846	0.853	0.854
300	0.877	0.867	0.883	0.875	0.894	0.890
450	0.882	0.878	0.905	0.893	0.918	0.912
600	0.885	0.886	0.921	0.906	0.936	0.928

Estimating empty body gain (EBG) from the average daily gain (ADG)

First, an assessment of the relationship between the SADG (measured from two weightings after fasting) and the ADG (measured from two weightings in fed status), regressed as a function of the SADG, showed that the intercept and the coefficient of inclination did not differ from 0 and 1 (P>0.14 and P>0.39, respectively). Therefore, the differences between SADG and ADG are not significant and the use of a single measurement, referenced only as ADG, can be adopted. That is, although they are theoretically different, in practice, SADG and ADG do not differ.

Statistical gains were not observed for the fitting of independent models instead of a single model as a function of feeding systems (P>0.16), sex (P>0.24) or genetic group (P>0.11). A single nonlinear model was therefore fitted to describe the relationship between EBG and ADG, as follows:

$$EBG = 0.9630 \times ADG^{1.0151}$$

Eq. 1.10

where EBG = empty body gain and ADG = average daily gain or average daily gain in fasting.

An example of applying Eq. 1.10 is shown in Table 1.7. The EBG/ADG ratio ranged from 0.943–0.971, when considering gains of 0.25–1.75 kg/d. The previous edition of the BR-CORTE suggested using a fixed EBG/ADG ratio 0.955 for animals on pasture and 0.936 and 0.966 for Zebu and their crosses, respectively, on feedlot. The NRC (2000) uses a fixed relation of 0.951. The data in Table 1.7 show that the estimates proposed from Eq. 1.10 are in agreement with the data in the literature. Nevertheless, there is a gain in precision and accuracy with the use of a variable EBG/ADG ratio, obtained from the nonlinear model, as proposed for this edition of the BR-CORTE.

Table 1.7 - Ratio between the empty body gain and average daily gain (EBG/ADG) based on applying Eq. 1.10

ADG (kg/d)	EBG (kg/d)	EBG/ADG	Decrease in ADG (%)
0.25	0.24	0.943	5.7
0.50	0.48	0.953	4.7
0.75	0.72	0.959	4.1
1.00	0.96	0.963	3.7
1.25	1.21	0.966	3.4
1.50	1.45	0.969	3.1
1.75	1.70	0.971	2.9

WEIGHT ADJUSTMENTS FOR ADULT COWS AS FUNCTION OF FEEDING AND PHYSIOLOGICAL STATUS

The weight ratios presented until now are applicable to growing and finishing animals, in a condition of physiological homeostasis. That is, they are applicable to healthy animals, in a positive growth phase (intake > maintenance), that have not yet reached physiological maturity. In the case of females that have already reached physiological maturity, weight adjustment as a function of fed status and physiological state (pregnant or not) was described by Gionbelli et al. (2015) using Nellore multiparous cows. The study by Gionbelli et al. (2015) is used as base for proposed weight adjustments for adult cows in this edition of the BR-CORTE, and the information described in this item was used from the referred study.

To adjust pregnant cow weight, Gionbelli et al. (2015) suggested the concept of pregnant compound (PREG) as represented by:

$$PREG = (UTpreg - UTnp) + (UDpreg - UDnp) \quad \text{Eq. 1.11}$$

where PREG = pregnant compound, UTpreg = weight of the pregnant or gravid uterus, UTnp = weight of the non-pregnant uterus, UDpreg = udder weight of the pregnant cow and UDnp = udder weight for the cow in non-pregnant status. Then, the PREG value includes the increase in weight in the uterus that occurs as a function of pregnancy (pregnant uterus minus non-pregnant uterus) plus the increase in udder weight due to pregnancy (udder in the pregnant condition minus the udder of the cow in non-pregnant condition).

The use of PREG allows to estimate portion of the weight of a pregnant cow that is function of pregnancy and the portion of the weight that is a function of the maternal tissues.

The “gestational weight’ of a cow is therefore separated from its “empty weight”, regardless of the gestational stage. In general, pregnancy (referenced by PREG) is considered mathematically as an extra component of the cow. Thus, for example, the weight gain of a cow can be calculated over a period relative to the increase in maternal tissues and the weight gain due to pregnancy. Therefore, the concepts of gestational weight (BWpreg, SBWpreg, and EBWpreg) and non-gestational or non-pregnant weight (BWnp, SBWnp and EBWnp) were created; their relationships are simply described by:

$$BWpreg = BWnp + PREG$$

$$SBWpreg = SBWnp + PREG$$

$$EBWpreg = EBWnp + PREG$$

The weights adjusted to the pregnant and non-pregnant condition are also the base for calculating the nutritional requirements for adult cows for maintenance and pregnancy, described in Chapter 10.

The equations used to estimate the fed, shrunk or empty body weight for non-pregnant and pregnant cows are described in Table 1.8. The detailed description of the abbreviations used in the equations presented in Table 1.8 is shown in Table 1.9. Because estimates of pregnant cow weight ratios require the use of several equations (Table 1.8), Gionbelli et al. (2015) prepared an Excel spreadsheet to facilitate calculations. This spreadsheet can be downloaded directly from the site of the journal where the study was published (open access study), using the link: <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0112111>.

Table 1.8 - Equations used to adjust weight of pregnant and non-pregnant Zebu cows

Variable to be estimated	Predicting variables	Ratio	Equation
		Non-pregnant cows	
SBWnp	BW	$SBWnp = 0.8084 \times BWnp^{1.0303}$	Eq. 1.12
EBWnp	SBW	$EBWnp = 0.8424 \times SBWnp^{1.0122}$	Eq. 1.13
		Pregnant cows	
SBWpreg	BWpreg	$SBWpreg = 0.8084 \times BWpreg^{1.0303}$	Eq. 1.12
BWnp	BWpreg and PREG	BWnp = BWpreg – PREG	Eq. 1.14
SBWnp	SBWpreg and PREG	SBWnp = SBWpreg – PREG	Eq. 1.15
PREG	If TG ≤ 240: UTfg If TG > 240: UTfg and UDfg	If TG ≤ 240: PREG=UTfg If TG > 240: PREG = UTfg + UDfg	Eq. 1.16
UTfg	UTpreg and UTnp	UTfg = UTpreg -UTnp	Eq. 1.17
UTpreg	TG or TG and BCS	$UTpreg = 0.008010 \times CBW \times BCS^{0.3225} \times \exp^{((0.02544 - 0.0000286 \times TG) \times TG)}$ or $UTpreg = 0.007521 \times CBW \times \exp^{((0.03119 - 0.00004117 \times TG) \times TG)}$	Eq. 1.18 Eq. 1.19
UTnp	SBWpreg and UTpreg	If TG ≤ 240: $UTnp = 0.0012 \times (SBWpreg - UTpreg + 0.6)$ If TG > 240: $UTnp = 0.0012 \times (SBWpreg - UTpreg + 0.6 - 2)$	Eq. 1.20
UDnp	UTfg, SBWpreg and BCS	If TG ≤ 240: $UDnp = (SBWpreg - UTfg) \times 0.00589 \times BCS^{0.2043}$ If TG > 240: $UDnp = (SBWpreg - UTfg - 2) \times 0.00589 \times BCS^{0.2043}$	Eq. 1.21
UDfg	UDnp and TG	If TG ≤ 240: UDfg = 0 If TG > 240: $UDfg = UDnp \times \exp^{((TG - 238) \times 0.0109)} - UDnp$	Eq. 1.22
EBWpreg	EBWnp and PREG	EBWpreg = EBWnp + PREG	Eq. 1.23
EBWnp	SBWnp	$EBWnp = 0.8424 \times SBWnp^{1.0122}$	Eq. 1.13

Table 1.9 - List of abbreviations (in alphabetical order) used in the equations presented in Table 1.8 and the definitions

Abbreviation	Definition
BCS	Body condition score (scale 1 to 9). When not available, use BCS=5
BWpreg	Pregnant body weight (kg)
BWnp	Non-pregnant body weight (kg)
CBW	Estimated weight of calf at birth (kg). It is suggested to use the mean weight of calves of the herd for which the estimates are being made.
EBWpreg	Pregnant empty body weight (kg)
EBWnp	Non-pregnant empty body weight (kg)
PREG	Pregnant compound (kg)
SBWpreg	Pregnant shrunk body weight (kg)
SBWnp	Non-pregnant shrunk body weight (kg)
TG	Days pregnant (d)
UDfg	Udder weight that increased as a function of pregnancy (kg)
UDnp	Udder weight for non-pregnant status (kg)
UTfg	Uterus weight that increased as a function of pregnancy (kg)
UTpreg	Weight of pregnant or gravid uterus (kg)
UTnp	Uterus weight for non-pregnant status (kg)

To show the applications of the equations and relationships shown in Table 1.8 (Gionbelli et al., 2015), we took as base a Nellore cow, with 450 kg BW (weight obtained in the field, without fasting), BCS = 4.5 and five months pregnant (TG = 150 days). Assuming that the same cow has been weighed again four months later, when the following data were obtained: BW = 520 kg, BCS = 5 and TG = 270. It is further considered that the mean weight at birth of the calves from such herd would be 35 kg (CBW = 35 kg). The equations and ratios presented in Table 1.8 can be used to estimate the shrunk and empty body weight and maternal constituents weight along with the pregnant compound, in the two weightings carried out, as follows:

First weighing	Second weighing (four months later)
BW = 450 kg / BCS = 4.5 / TG = 150 days / CBW = 35 kg	BW = 520 kg / BCS = 5 / TG = 270 days / CBW = 35 kg
SBWpreg = 0.8084 × $BWpreg^{1.0303}$ (Eq. 1.12) SBWpreg = 0.8084 × $450^{1.0303}$ = 437.76 kg	SBWpreg = 0.8084 × $BWpreg^{1.0303}$ (Eq. 1.12) SBWpreg = 0.8084 × $520^{1.0303}$ = 508.07 kg
UTpreg = 0.00801 × CBW × $BCS^{0.3225}$ × $\exp^{((0.02544 - 0.0000286 \times TG) \times TG)}$ (Eq. 1.18) UTpreg = 0.00801 × 35 × $4.5^{0.3225}$ × $\exp^{((0.02544 - 0.0000286 \times 150) \times 150)}$ = 10.87 kg	UTpreg = 0.00801 × CBW × $BCS^{0.3225}$ × $\exp^{((0.02544 - 0.0000286 \times TG) \times TG)}$ (Eq. 1.18) UTpreg = 0.00801 × 35 × $5^{0.3225}$ × $\exp^{((0.02544 - 0.0000286 \times 270) \times 270)}$ = 56.33 kg
UTnp = 0.0012 × (SBWpreg – UTpreg + 0.6) (Eq. 1.20) UTnp = 0.0012 × (437.76 – 10.87 + 0.6) = 0.51 kg	UTnp = 0.0012 × (SBWpreg – UTpreg + 0.6 – 2) (Eq. 1.20) UTnp = 0.0012 × (508.07 – 56.33 + 0.6 – 2) = 0.54 kg
UTfg = UTpreg – UTnp (Eq. 1.17) UTfg = 10.87 – 0.51 = 10.36 kg	UTfg = UTpreg – UTnp (Eq. 1.17) UTfg = 56.33 – 0.54 = 55.79 kg
UDnp = (SBWpreg – UTfg) × 0.00589 × $BCS^{0.2043}$ (Eq. 1.21) UDnp = (437.76 – 10.36) × 0.00589 × $4.5^{0.2043}$ = 3.42 kg	UDnp = (SBWpreg – UTfg) × 0.00589 × $BCS^{0.2043}$ (Eq. 1.21) UDnp = (508.07 – 55.79) × 0.00589 × $5^{0.2043}$ = 3.68 kg
UDfg = 0 kg (Eq. 1.22)	UDfg = UDnp × $\exp^{((TG-238) \times 0.0109)}$ – UDnp (Eq. 1.22) UDfg = 3.68 × $\exp^{((TG-238) \times 0.0109)}$ – 3.68 = 1.54 kg
PREG = UTfg (Eq. 1.16) PREG = 10.36 kg	PREG = UTfg + UDfg (Eq. 1.16) PREG = 55.79 + 1.54 = 57.33 kg
SBWnp = SBWpreg – PREG (Eq. 1.15) SBWnp = 437.76 – 10.36 = 427.40 kg	SBWnp = SBWpreg – PREG (Eq. 1.15) SBWnp = 508.07 – 57.33 = 450.75 kg
EBWnp = 0.8424 × $SBWnp^{1.0122}$ (Eq. 1.13) EBWnp = 0.8424 × $427.40^{1.0122}$ = 387.66 kg	EBWnp = 0.8424 × $SBWnp^{1.0122}$ (Eq. 1.13) EBWnp = 0.8424 × $450.75^{1.0122}$ = 409.10 kg
EBWpreg = EBWnp + PREG (Eq. 1.23) EBWpreg = 387.66 + 10.36 = 398.01 kg	EBWpreg = EBWnp + PREG (Eq. 1.23) EBWpreg = 409.10 + 57.33 = 466.42 kg
Interpretation: over 120 days the cow gained 70 kg in weight (520 - 450). In this period, however, the cow increased 46.97 kg in weight relative to pregnancy (57.33 – 10.36). This corresponds to an average daily gain of 0.39 kg for pregnancy. The shrunk weight gain for maternal tissues in the period was only 21.44 kg (409.10 – 387.66), that corresponds to an average daily gain of 0.18 kg for maternal tissues disposition. That is, from the total shrunk body weight gain of the cow in the period (68.41 kg), 68.7% was relative to pregnancy and 31.3% was relative to maternal tissue deposition.	

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