PREDICTION OF BODY AND CARCASS CHEMICAL COMPOSITION OF PUREBRED AND CROSSBRED NELLORE CATTLE

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INTRODUCTION

The first step to determine the nutritional requirements of cattle is to measure their body composition. The methods used to predict body (or carcass) composition can be classified as direct or indirect. Indirect methods involve predicting the composition of the body (or carcass) based on easily obtained parameters. Direct methods involve separating and dissecting all of the animal's body parts and determining their physical and chemical constituents. Thus, experiments involving the use of direct methods are extremely laborious, time-consuming and expensive due to loss of at least half of the carcass and the large number of people and laboratory analyses involved.

Several indirect methods have been developed and used to different extents around the world. Kraybill et al. (1952) developed a method of estimating water and body ether extract by specific gravity. This tool has seen some use in Brazil (Alleoni et al. 1997; Lanna et al. 1995; Peron et al. 1993, Gill et al. 1991), but it generally has not produced good results for Zebu cattle (Lanna et al. 1995; Alleonni et al. 1997). Other methods, such as antipyrine, tritiated water, N-acetyl-amino-antipyrine (Panareto and Till, 1963), urea dilution (Preston and Kock, 1973) and ^{40}K (Clark et al., 1976) have not been used in Brazil due to difficulty of the techniques, cost and/or lack of equipment and adequate instruction.

The most commonly used method in Brazil was proposed by Hankins and Howe (1946), who developed equations for estimating the body composition of cattle based on a 9-10-11th rib cut (Rib_{9-11}). This technique has been widely used because it is easy, fast and inexpensive, and it has produced good results in some studies (Paulino et al. 2005a; Henry et al., 2003; Silva, 2001).

USE OF THE 9-10-11th RIB CUT – RIB_{9-11}

Hankins and Howe (1946) conducted an experiment on the use of bovine carcass cuts for predicting their physical and chemical composition. They introduced a methodology for obtaining a sample of the carcass comprising the section between the 9th and 11th ribs (Rib_{9-11}), and they established equations that predict its composition. The authors' work was based on results obtained by other researchers, notably Trowbridge and Haigh (1921, 1922), Moulton (1923) and Lush (1926), who tested different cuts of the carcass for their physical predictability and concluded that the rib was the portion that best represented the carcass. Back in that time, though, Lush (1926) emphasized the importance of determining not only the composition of the carcass, but also of the entire empty body, so that the results would be more useful for experiments in animal nutrition.

Rib_{9-11} is defined (as shown in Figure 1) by measuring the distance between the first and last point of the rib bone (distance from A to B) and calculating 61.5% of this distance (point C). The Rib_{9-11} cut must be done at point D, which is defined as the point where a line perpendicular to the ruler passes through point C.

Hankins and Howe (1946) defined several equations to predict the physical and chemical composition of a carcass. These authors worked only with steers and heifers, defining models for these gender classes and a general equation that would cover both. A problem arising from the equations suggested by Hankins and Howe (1946) is that the predictive equations for chemical composition only encompass the edible tissue of the carcass, and therefore do not account for bone composition. This may be a explanation for the varied results obtained in experiments designed to validate these equations (Cole et al. 1962; Powell and Huffman, 1968; Dikeman and Crouse, 1974; Thonney and Nour, 1994).

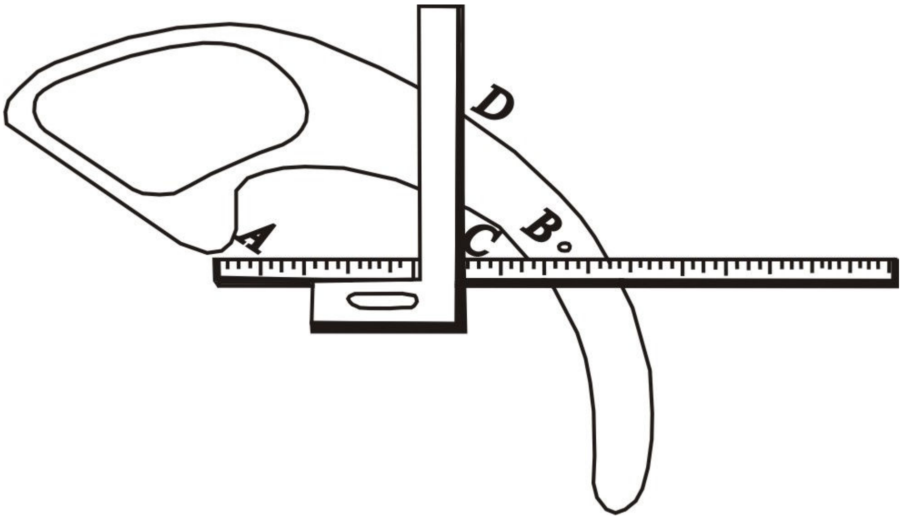

Figure 1 - Illustration of the HH section cutting method (Hankins and Howe, 1946).

The equations proposed by Hankins and Howe (1946) to predict the physical and chemical composition of the carcass are presented in Table 1.

Table 1 - Equations used to estimate physical and chemical carcass composition from the composition of the Rib_{9-11}, as proposed by Hankins and Howe (1946)

Variables	Gender		
	All	**Steers**	**Heifers**
		Physical composition	
Carcass fat, % (Y) Rib_{9-11} fat, % (X)	**Y = 3.06 + 0.82 X**	**Y = 3.54 + 0.80 X**	**Y = 3.14 + 0.83 X**
Carcass lean, % (Y) Rib_{9-11} lean, % (X)	**Y = 15.56 + 0.81 X**	**Y = 16.08 + 0.80 X**	**Y = 16.09 + 0.79 X**
Carcass bones, % (Y) Rib_{9-11} bones, % (X)	**Y = 4.30 + 0.61 X**	**Y = 5.52 + 0.57 X**	**Y = 6.88 + 0.44 X**
		Chemical composition	
Carcass ether extract, % (Y) Rib_{9-11} ether extract, % (X)	**Y = 2.82 + 0.77 X**	**Y = 3.49 + 0.74 X**	**Y = 2.73 + 0.78 X**
Carcass protein, % (Y) Rib_{9-11} protein, % (X)	**Y = 5.98 + 0.66 X**	**Y = 6.19 + 0.65 X**	**Y = 5.64 + 0.69 X**
Carcass water, % (Y) Rib_{9-11} water, % (X)	**Y = 14.90 + 0.78 X**	**Y = 16.83 + 0.75 X**	**Y = 14.28 + 0.78 X**

Although the equations proposed by Hankins and Howe (1946) are widely used abroad and in Brazil, few studies have been conducted to determine whether they are applicable to Zebu cattle that dominate Brazilian livestock, since the equations were developed using *Bos taurus*. Lana (1988), Silva (2001), Paulino et al. (2005a,b) and Marcondes et al. (2009) dissected the carcasses of some animals and evaluated Rib_{9-11} as an indicator of carcass composition and empty body composition and concluded (unanimously) that the equations developed by Hankins and Howe (1946) were not fully applicable to Zebu cattle. The adipose tissue and ether extract were the constituents with the largest variation, since the use of these equations for Zebu cattle incurred in overestimations of fat content in the carcass and empty body. As Hankins and Howe (1946) equations did not compute bone tissue when estimating carcass chemical composition, it is likely that this is one of the reasons for the problems in estimating adipose tissue and ether extract in the carcass or in the empty body of Zebu cattle. Because bones have a much lower concentration of these components, the final predictions are usually overestimated (Marcondes et al., 2010a).

Some studies were conducted in Brazil aiming the prediction of body and carcass chemical compositions from the chemical composition of Rib_{9-11} (Ferreira et al. 2001; Véras et al., 2001, Jorge et al. 2000; Peron et al., 1993). However, all of these researchers chemically analyzed samples of muscle, fat and bone obtained by dissection of Rib_{9-11} and estimated the chemical composition of the section from these data. The results were then extrapolated to the carcass using the equations developed by Hankins and Howe (1946). The carcass chemical composition was consequently "estimated" from chemical analysis of Rib_{9-11}, and body composition was determined by adding up the data found by analyzing other non-carcass tissues. As the carcass is the main quantitative component of the empty body, the vast majority of these studies concluded that body composition could be predicted from the chemical composition of Rib_{9-11}, which seems not to be true, especially regarding the carcass ether extract (Smith, 2001, Paulino et al., 2005a).

Thus, some authors developed equations (Table 2) for Zebu cattle with greater emphasis being given to fat, which is the most variable component of the body (Paulino et al., 2005a, b; Henrique et al., 2003; Silva, 2001; Alleoni et al. 2001; Lanna, 1988). Paulino et al. (2003) validated some of these equations and found that only the equation developed by Lanna (1988) was able to estimate without bias the content of ether extract in the empty body of Zebu animals.

Table 2 - Equations used to estimate empty body weight (EBW) chemical composition of Zebu cattle from Rib_{9-11} chemical composition according to different authors

Author	Genetic group	Body component	Equation
Lanna (1988)	Nellore bulls	Water in the empty body weight	Water in the EBW (%) = 24.1936 + 0.6574 x water in the Rib_{9-11} (%) r^2 = 0.93; Syx = 0.8
Lanna (1988)	Nellore bulls	Ether extract in the empty body weight	EE in the EBW (%) = 8.938 + 0.01605 x (EE in the Rib_{9-11})^2 r^2 = 0.95; Syx = 0.8
Lanna (1988)	Nellore bulls	Protein in the empty body weight	Ratio of Protein:water in the EBW = 0.3077
Alleoni et al. (2001)	Brangus bulls	Water in the empty body weight	Water in the EBW (%) = 0.1413 + 1.0255 x water in the Rib_{9-11} (%) r^2 = 0.946; Syx = 0.734
Alleoni et al. (2001)	Brangus bulls	Ether extract in the empty body weight	EE in the EBW (%) = 90.14538 – 1.21282 x water in the Rib_{9-11} (%) r^2 = 0.853; Syx = 1.503
Alleoni et al. (2001)	Brangus bulls	Protein in the empty body weight	Ratio of Protein:water in the EBW = 0.2806
Silva (2001)	Nellore bulls	Water in the empty body weight	Water in the EBW (%) = 66.7493 – 0.4251 x EE in the Rib_{9-11}(%) r^2 = 0.51
Silva (2001)	Nellore bulls	Ether extract in the empty body weight	EE in the EBW (%) = 5.3424 + 0.6020 x EE in the Rib_{9-11}(%) r^2 = 0.56
Silva (2001)	Nellore bulls	Protein in the empty body weight	Protein in the EBW (%) = 17.9987 – 0.1584 x Protein in the Rib_{9-11}(%) r^2 = 0.59
Henrique et al. (2003)	Santa Gertrudes bulls	Water in the empty body weight	Water in the EBW (%) = 1.1221 x water in the Rib_{9-11}(%) – 6.4839 r^2 = 0.95; Syx = 0.97
Henrique et al. (2003)	Santa Gertrudes bulls	Ether extract in the empty body weight	EE in the EBW (%) = -1.1570 x water in the Rib_{9-11}(%) + 84.2600 r^2 = 0.92; Syx = 1.33
Paulino et al. (2005b)	Nellore steers	Water in the empty body weight	Water in the EBW (%) = 6.67 + 0.924 x water in the Rib_{9-11}(%) r^2 = 0.89; Syx = 1.482
Paulino et al. (2005b)	Nellore steers	Ether extract in the empty body weight	EE in the EBW (%) = 0.573 + 0.840 x EE in the Rib_{9-11}(%) r^2 = 0.93; Syx = 1.572
Paulino et al. (2005b)	Nellore steers	Protein in the empty body weight	Protein in the EBW (%) = 5.01 + 0.782 x Protein in the Rib_{9-11}(%) r^2 = 0.93; Syx = 0.4755

r^2 = coefficient of determination; Sxy = standard error of prediction.

In the first edition of the Brazilian Tables of Nutrient Requirements of Zebu Beef Cattle (BR-CORTE, Valadares Filho et al., 2006), equations were developed using results from complete dissection of carcass and Rib_{9-11} (N = 66) conducted by Paulino (2002 and 2006) to predict carcass and empty body chemical composition of Zebu cattle (Tables 3 and 4) using the Rib_{9-11}.

Table 3 - Equations used to estimate empty body weight (EBW) chemical composition of Zebu cattle from Rib_{9-11} chemical composition

Variables	Equation	Standard error of the estimate	Coefficient of determination
Water in the empty body weight, % (Y)			
Water in the Rib_{9-11}, % (X)	**Y = 31.42 + 0.51 X**	**1.94**	**0.71**
Ether extract in the empty body weight, % (Y)			
Ether extract in the Rib_{9-11}, % (X)	**Y = 4.56 + 0.60 X**	**2.37**	**0.81**
Protein in the empty body weight, % (Y)			
Protein in the Rib_{9-11}, % (X)	**Y = 4.96 + 0.76 X**	**0.90**	**0.75**
Minerals in the empty body weight, % (Y)			
Minerals in the Rib_{9-11}, % (X)	**Y = 2.54 + 0.39 X**	**0.47**	**0.45**

Table 4 - Equations used to estimate carcass chemical composition of Zebu cattle from Rib_{9-11} chemical composition

Variables	Equation	Standard error of the estimate	Coefficient of determination
Water in the carcass, % (Y)			
Water in the Rib_{9-11}, % (X)	Y = 34.97 + 0.45 X	1.94	0.66
Ether extract in the carcass, % (Y)			
Ether extract in the Rib_{9-11}, % (X)	Y = 4.96 + 0.54 X	2.22	0.80
Protein in the carcass, % (Y)			
Protein in the Rib_{9-11}, % (X)	Y = 4.05 + 0.78 X	1.00	0.72
Minerals in the carcass, % (Y)			
Minerals in the Rib_{9-11}, % (X)	Y = 2.88 + 0.50 X	0.66	0.40

These equations, presented in the 2006 BR-CORTE, underwent an evaluation by Marcondes et al. (2010a), who assembled a database with 263 animals independent of those used by Valadares Filho et al. (2006). The database consisted of bulls, steers and heifers, as well as Nellore, Angus x Nellore and Simmental x Nellore crossbred animals. They had their right half carcass and Rib_{9-11} completely dissected for comparison. The authors also performed a new evaluation of the equations suggested by Hankins and Howe (1946) and compared them with those proposed in the first edition of BR-CORTE.

Marcondes et al. (2010a) concluded that, in general, the equations proposed by Hankins and Howe (1946) and BR-CORTE (Valadares Filho et al., 2006) successfully estimated the carcass and empty body chemical composition, where BR-CORTE equations yielded the best estimates. The primary index used by the authors for evaluation was the concordance correlation coefficient (CCC), which can theoretically evaluate precision and accuracy simultaneously (Lin, 1989). The closer the CCC is to a value of one, the more precise and accurate the model is, where lower CCC values indicate less accuracy and/or precision of the model.

Marcondes et al. (2010a) reported good results (CCC values between 0.70 and 0.91) for the estimating equations for ether extract and water in the carcass and empty body published by Valadares Filho et al. (2006) and Hankins and Howe (1946); however, crude protein estimates were less precise and/or accurate (CCC values between 0.56 and 0.61). The authors explained that the inclusion of new variables in the models and effects such as gender and breed could improve the fitness of the equations.

In the first version of the BR-CORTE, Valadares Filho et al. (2006) suggested that complete dissection and whole carcass grinding, which is used in experiments where the researcher intends to determine nutritional requirements, should be recommended and used again until an adequate amount of information is generated. Thereafter, more comprehensive and representative equations could be developed that encompass a broader range of applications.

To determine the chemical composition of the empty body in an efficient, fast and cost-effective way it will be essential to develop more comprehensive and reliable equations. A meta-analysis of all available individual data could make this possible, and it should help to decrease the gap that now exists between conducting experiments and disseminating the results.

Consequently, Marcondes et al. (2010a) combined the data used in the assessment with those used by Valadares Filho et al. (2006) and formed a new database with 247 animals and six experiments (Souza et al., 2010, Marcondes et al. 2010b; Paulino et al., 2009, Marcondes et al. 2009; Chizzotti et al., 2008; Paulino et al., 2005b) conducted with purebred Nellore or Nellore crossbred with Angus or Simmental animals (Table 5). The authors studied the inclusion of new variables in the model, as well as effects of breed, gender and study, and the final models are presented in Tables 6 and 7.

Table 5 - Description of data used to develop prediction equations of body composition of Zebu cattle from the Rib_{9-11}

Item	Mean	SD	Maximum	Minimum
Empty body weight, kg	328	78.8	506	176
Carcass weight, kg	206	50.3	323	99.7
Organs plus viscera, % EBW	15.3	1.6	21.8	12.2
Visceral fat, % EBW	4.6	1.6	8.8	1.4
Ether extract in the EBW, %	18.15	5.60	29.95	4.15
Protein in the EBW, %	17.60	1.62	23.38	12.92
Water in the EBW, %	58.46	4.27	71.41	49.07
Ether extract in the carcass, %	17.87	5.20	29.84	3.87
Protein in the carcass, %	17.31	1.93	28.52	12.35
Water in the carcass, %	57.98	3.91	73.54	43.91
Fat in the carcass, %	20.7	6.3	33.6	7.3
Lean in the carcass, %	61.8	4.2	73.1	52.8
Bones in the carcass, %	17.5	3.0	28.1	12.6
Ether extract in the Rib_{9-11}, %	23.18	8.91	50.85	4.85
Protein in the Rib_{9-11}, %	16.71	2.07	23.97	11.38
Water in the Rib_{9-11}, %	52.76	6.53	67.62	29.29
Fat in the Rib_{9-11}, %	28.1	9.00	50.6	7.0
Lean in the Rib_{9-11}, %	53.4	7.2	71.4	25.0
Bones in the Rib_{9-11}, %	18.7	3.9	32.7	11.4

SD= standard deviation.

Table 6 - Equations used to estimate carcass chemical composition of Zebu cattle from the Rib_{9-11} and other body variables

Component	Genetic group	Equation[1]	R^2	RMSE[3]
Ether extract	-	EE_C (%) = 4.31 + 0.31 × $EE_{Rib9-11}$ + 1.37 × VF	0.83	2.13
Protein		CP_C (%) = 17.92 + 0.60 × $CP_{Rib9-11}$ – 0.17 × CD	0.50	1.26
	Nellore	W_C (%) = 48.74 + 0.28 × $W_{Rib9-11}$ – 0.017 × EBW		
Water	NA	W_C (%) = 46.69+ 0.32 × $W_{Rib9-11}$ – 0.017 × EBW	0.67	2.27
	NS	W_C (%) = 38.06+ 0.48 × $W_{Rib9-11}$ – 0.017 × EBW		

[1] EE_C = ether extract in the carcass. $EE_{Rib9-11}$ = ether extract in the Rib_{9-11}. VF = percentage of visceral fat in the empty body weight. CP_C = crude protein in the carcass. $CP_{Rib9-11}$ = protein in the Rib_{9-11}. CD = carcass dressing. W_C = water in the carcass. W_{HH} = water in the Rib_{9-11}; EBW = empty body weight; [3]RMSE = Root mean square error.

Table 7 - Prediction equations of empty body weight chemical composition of Zebu cattle from the Rib_{9-11} and other body variables

Component	Gender	Equation[1]	R^2	RMSE[3]
Ether extract	Bulls	EE_{EBW} = 2.75+ 0.33 × $EE_{Rib9-11}$ + 1.80 × VF		
	Steers	EE_{EBW} = 1.84+ 0.33 × $EE_{Rib9-11}$ + 1.91 × VF	0.89	1.97
	Heifers	EE_{EBW}= 4.77 + 0.33 × $EE_{Rib9-11}$ + 1.28 × VF		
Protein		CP_{EBW} = 10.78+ 0.47 × $CP_{Rib9-11}$ – 0.21 × VF	0.59	1.03
	Bulls	W_{EBW} = 38.31+ 0.33 × $W_{Rib9-11}$ – 1.09 × VF + 0.50 × OV		
Water	Steers	W_{EBW} = 45.67 + 0.25 × $W_{Rib9-11}$ – 1.89 × VF + 0.50 × OV	0.82	1.96
	Heifers	W_{EBW} = 31.61 + 0.47 × $W_{Rib9-11}$ – 1.06 × VF + 0.50 × OV		

[1] EE_{EBW} = ether extract in the empty body weight. $EE_{Rib9-11}$ = ether extract in the Rib_{9-11}. VF = percentage of visceral fat in the empty body weight. CP_{EBW} = protein in the empty body weight. $CP_{Rib9-11}$ = protein in the Rib9-11. W_{EBW} = water in the empty body weight. $W_{Rib9-11}$ = water in the Rib_{9-11}. OV = percentage of organs plus viscera in the empty body weight; [3]RQME = root mean square error.

According to Marcondes et al. (2010a), the equations showed good precision and accuracy, and their use will provide important advances in the prediction of animal body composition and will reduce the cost of experiments. According to the authors, the inclusion of new variables into the model and the inclusion of breed and gender effects provided better estimates. Among them, the inclusion of visceral fat was extremely important, because carcass fat is the most variable component. Then the visceral fat jointly with other variables could indicate better the metabolic pattern of the animal. The visceral fat variable used by the authors consisted of the physical separation of the mesenteric fat plus renal, pelvic and cardiac fats. The effect of feeding level on body composition has been extensively discussed in the literature (Nour and Thonney, 1987, Williams et al., 1983, Nour et al., 1981, Ferrell et al. 1978; Prior et al., 1977), therefore, an indicator of the feeding level, which visceral fat was in the equations, is extremely important for the applicability of the equations.

Marcondes et al. (2010b) studied the relationship between fat-free dry matter and the composition of the empty body weight (EBW). Reid et al. (1955) suggested that the body ether extract could be estimated by the water content of the body, and they also indicated that the protein/ash ratio in the body would be constant in the fat-free dry matter, being affected only by the age.

Using a database of 272 animals (Table 8) Marcondes et al. (2010b) proposed the equation shown below to estimate the body ether extract based on water according to a model suggested by Reid et al. (1955). There was no evident effect of breed or gender on the regression parameters; the model had an R^2 of 0.96 and RMSE of 1.26.

Table 8 - Description of data used to develop prediction equations of body composition

Itens	Mean	SD	Maximum	Minimum
Empty body weight, kg	323.82	75.72	506.08	145.86
Carcass weight, kg	202.77	48.92	322.45	87
Carcass dressing, %	62.53	2.11	71.86	50.49
Organs plus viscera, % EBW	14.85	1.39	19.76	12.17
Visceral fat, % EBW	3.95	1.53	8.75	1.4
Ether extract in the EBW, %	15.77	6.07	29.95	4.15
Protein in the EBW, %	18.17	1.47	23.38	14.29
Ether extract in the Rib_{9-11}, %	19.83	9.02	50.85	4.85
Protein in the Rib_{9-11}, %	17.18	1.77	23.38	11.38

SD – Standard deviation.

$$EE_{EBW} = 236.21 - 126.25 \times \log(W_{EBW}) + 1.114 \times VF$$

where EE_{EBW} is the ether extract (%) of empty body weight, W_{EBW} is the water (%) of empty body weight and VF is visceral fat (%) of empty body weight.

Knowing the proportion of body fat, it would be possible to estimate the concentration of protein in the empty body fat-free dry matter. However, unlike Reid et al. (1955), who correlated the protein/ash ratio with age, Marcondes et al. (2010b) correlated this ratio with EBW, because different nutritional plans may provide different body weights at the same age, with resulting differences in body composition. Thus, the equation suggested by the authors is shown below, and the ash could then be estimated as 100 - crude protein in fat-free dry matter.

$$CPFFDM_{EBW} = 74.09 + 0.0098 \times EBW$$

where $CPFFDM_{EBW}$ is crude protein (%) in the fat-free dry matter of the empty body weight and EBW is empty body weight (kg).

PREDICTION OF THE EMPTY BODY MINERAL COMPOSITION

Only two studies were found in the literature that aimed to evaluate Rib_{9-11} as a possible indicator of the macromineral composition (calcium, phosphorus, sodium, potassium and magnesium) of the empty body (Paulino, 2002 and Marcondes et al., 2009). Although it is still in its early stages, the work of Marcondes et al. (2009) suggested that there is a good correlation between the mineral components found in Rib_{9-11} and in the empty body. The authors grouped data (N = 19) used by Paulino (2002) with a new experiment containing 27 animals (Table 9) to predict the minerals in the empty body. The effects of gender and study were not evaluated because this would require a greater database.

The adjusted equations were promising, as indicated by the r^2 values (Table 10). In the study by Marcondes et al. (2009), a stabilizing trend for the mineral content of the empty body was noticed, especially for sodium, which may have caused a decrease in the coefficients of determination of the equation.

However, these equations still need to be evaluated, and the effects of gender and/or breed (and possibly other variables) should be tested to further develop the models.

Table 9 - Description of data used to develop prediction equations of empty body weight mineral composition of Zebu cattle

Itens	Mean	SD	Maximum	Minimum
Calcium in the EBW, %	2.110	0.559	3.600	1.191
Phosphorus in the EBW, %	0.834	0.118	1.096	0.634
Magnesium in the EBW, %	0.043	0.011	0.076	0.029
Sodium in the EBW, %	0.147	0.012	0.176	0.114
Potassium in the EBW, %	0.191	0.025	0.263	0.157
Calcium in the Rib_{9-11}, %	2.734	0.941	5.367	1.509
Phosphorus in the Rib_{9-11}, %	1.066	0.232	1.658	0.666
Magnesium in the Rib_{9-11}, %	0.054	0.014	0.091	0.035
Sodium, in the Rib_{9-11}, %	0.124	0.024	0.174	0.085
Potassium in the Rib_{9-11}, %	0.229	0.026	0.318	0.167

SD – Standard deviation.

Table 10 - Equations used to estimate empty body weight mineral composition of Zebu cattle

Itens	Equation[1]	r^2
Calcium	$Ca_{EBW} = 0.7334 + 0.5029 \times Ca_{Rib9-11}$	0.71
Phosphorus	$P_{EBW} = 0.3822 + 0.4241 \times P_{Rib9-11}$	0.70
Magnesium	$Mg_{EBW} = 0.0096 + 0.6260 \times Mg_{Rib9-11}$	0.73
Sodium	$Na_{EBW} = 0.1111 + 0.2886 \times Na_{Rib9-11}$	0.31
Potassium	$K_{EBW} = 0.0357 + 0.6732 \times K_{Rib9-11}$	0.60

[1] Ca_{EBW} = calcium in the empty body weight (%). $Ca_{Rib9-11}$ = calcium in the Rib_{9-11} (%); P_{EBW} = phosphorus in the empty body weight (%). $P_{Rib9-11}$ = phosphorus in the Rib_{9-11} (%). Mg_{EBW} = magnesium in the empty body weight (%). $Mg_{Rib9-11}$ = magnesium Rib_{9-11} (%). Na_{EBW} = sodium in the empty body weight (%). $Na_{Rib9-11}$ = sodium in the Rib_{9-11} (%). K_{EBW} = potassium in the empty body weight (%). $K_{Rib9-11}$ = potassium in the Rib9-11 (%).

CHEMICAL COMPOSITION OF NON-CARCASS COMPONENTS

When the chemical composition of Rib_{9-11} is employed as an estimator, the equations proposed in the first edition of the BR-CORTE (Tables 3 and 4) always yield a better prediction of the carcass chemical composition than empty body composition. Thus, if researchers decide to use the prediction equations which determine the carcass chemical composition, or if they choose to obtain the real composition of the carcass through its dissection and grinding, it is still necessary to determine the composition of non-carcass components (blood, hide, feet, head, organs and viscera) to obtain the empty body chemical composition.

Determination of the chemical composition of these non-carcass body constituents necessarily implies a greater time, cost and labor, because at least seven additional samples per animal would need to be taken to the laboratory. Furthermore, limbs and head dissection is extremely laborious, dangerous and difficult to implement as a routine procedure. Considering also that the carcass dressing in relation to empty body weight would be around 60 - 65% (Missio et al., 2009, Costa et al., 2005), all the non-carcass components together would represent 35 to 40% of the empty body weight. Thus, all the work needed to determine its chemical composition would have a negative cost-benefit relationship because its impact on the estimated empty body chemical composition would be smaller than the impact of carcass chemical composition.

In a study by Marcondes et al. (2010c, unpublished data), the possibility of estimating the compositions of the blood, hide, feet and head were evaluated to reduce the experimental work and cost.

The authors have assembled a database of 335 animals (Tables 11, 12 and 13). Study was controlled as a random effect and breed and gender were tested as fixed effects. To estimate the composition of each non-carcass component, equations would need to be fitted for each of them (blood, hide, limbs, head, organs and viscera). However, assuming that models would be needed to estimate fat, protein, water and minerals, this procedure would create a large amount of equations, which would make its use impractical and confusing. Therefore, to simplify the methodology, non-carcass components were grouped to reduce the number of equations and to facilitate their estimation. A group with a high concentration of minerals and protein was formed by the head and limbs. A second group was consisted by blood plus hide, considering that both have a high proportion of protein in dry matter and that together they represent a small fraction of the empty body (on average 14.57% of EBW). Finally, equations were developed for organs and viscera.

Table 11 - Description of data used to develop prediction equations of blood and hide composition of Zebu cattle

Itens	**Mean**	**SD**	**Maximum**	**Minimum**
Empty body weight, kg	314.32	81.12	506.08	107.74
Organs and viscera, % EBW	15.94	4.84	49.14	12.17
Visceral fat, % EBW	3.96	1.73	8.75	0.21
Carcass weight, kg	193.30	51.98	322.45	63.75
Carcass dressing, % EBW	61.46	3.47	71.86	48.95
		Blood composition, % of EBW		
	3.75	0.53	5.59	2.49
Ether extract, %	0.16	0.14	0.90	0.00
Protein, %	18.87	2.36	25.20	10.14
Water, %	79.96	2.23	88.01	73.59
Minerals, %	0.85	0.43	3.73	0.37
Calcium, %	0.093	0.502	4.124	0.003
Phosphorus, %	0.019	0.005	0.047	0.006
Magnesium, %	0.005	0.004	0.059	0.001
Sodium, %	0.281	0.121	0.702	0.122
Potassium, %	0.046	0.022	0.115	0.019
		Hide composition, % of EBW		
	10.82	1.05	14.63	7.25
Ether extract, %	8.14	5.73	35.56	0.30
Protein, %	26.98	5.12	46.73	8.67
Water, %	64.31	6.00	88.06	44.06
Minerals, %	0.58	0.30	3.13	0.17
Calcium, %	0.039	0.024	0.147	0.011
Phosphorus, %	0.044	0.029	0.238	0.008
Magnesium, %	0.009	0.004	0.024	0.002
Sodium, %	0.170	0.068	0.510	0.023
Potassium, %	0.110	0.060	0.248	0.023

SD = Standard deviation.

Table 12 - Description of the data used to develop equations to predict the composition of head and limbs of cattle

Items	Average	SD	Maximum	Minimum
Empty body weight, kg	308.99	84.31	506.08	107.74
Organs and viscera,% EBW	17.14	7.20	49.14	12.35
Visceral fat,% EBW	4.09	1.63	8.75	1.40
Carcass weight, kg	192.21	54.16	322.45	63.75
Carcass dressing,% EBW	62.03	1.82	66.42	55.65
		Head composition, % of EBW		
Ether extract,%	9.91	2.89	16.27	4.00
Crude protein,%	18.62	1.30	21.88	15.79
Water,%	58.83	3.71	68.60	50.80
Ash,%	12.46	1.84	20.49	8.55
Calcium,%	4.4398	1.3423	6.9351	0.0367
Phosphorus,%	1.9183	0.7196	3.9878	0.0546
Magnesium,%	0.0810	0.0236	0.1252	0.0032
Sodium,%	0.2251	0.0766	0.3311	0.0594
Potassium,%	0.1151	0.0250	0.1605	0.0339
		Limbs, % of EBW		
Ether extract,%	11.84	2.61	21.01	6.38
Crude protein,%	24.38	2.89	31.38	16.63
Water,%	44.12	3.97	55.30	33.05
Ash,%	19.24	2.92	26.32	12.52
Calcium,%	7.3899	1.4545	11.1215	3.9510
Phosphorus,%	3.1317	0.8993	6.7626	1.5886
Magnesium,%	0.1004	0.0386	0.1992	0.0125
Sodium,%	0.2866	0.0780	0.4555	0.1225
Potassium,%	0.0668	0.0165	0.1130	0.0380

SD = standard deviation.

Table 13 - Description of data used to develop equations to predict the composition of the organs and viscera

Items	Average	SD	Maximum	Minimum
Empty body weight, kg	316.16	81.87	506.08	107.74
Organs plus viscera,% EBW	15.19	1.58	21.76	11.75
Visceral fat,% EBW	3.98	1.75	8.75	0.21
Carcass weight, kg	193.98	52.57	322.45	63.75
Carcass dressing,% EBW	61.31	3.50	71.86	48.95
Ether extract,%	33.24	15.16	80.71	4.30
Crude protein,%	10.91	2.74	27.38	5.12
Water,%	55.05	14.12	82.17	11.66
Ash,%	0.84	0.25	2.13	0.25
Calcium,%	0.084	0.053	0.273	0.013
Phosphorus,%	0.108	0.048	0.355	0.004
Magnesium,%	0.022	0.042	0.264	0.004
Sodium,%	0.102	0.046	0.425	0.034
Potassium,%	0.149	0.050	0.373	0.024

SD = standard deviation.

Overall, the equations adjusted to estimate the composition of blood and hide had a low r^2 (Table 14); however, this may be due more to low slope coefficients than to lack of precision of the equations, since the RMSE indicated good accuracy. Hence, the equations can be used to estimate the composition of hide plus blood without a significant loss of accuracy but with considerable reductions in cost and labor.

Table 14 - Equations used to estimate the chemical composition of blood and hide together

Component	Gender	Equation[1]	r^2	RMSE[2]
	Bulls	$EE_{BH} = -14.383 + 0.019 \times CW + 1.48 \times Hide_{EBW}$		
Ether extract	Steers	$EE_{BH} = -18.981 + 0.042 \times CW + 1.48 \times Hide_{EBW}$	0.34	3.02
	Heifers	$EE_{BH} = -17.295 + 0.042 \times CW + 1.48 \times Hide_{EBW}$		
Protein		$CP_{BH} = 24.895$	-	4.13
Water		$W_{BH} = 59.243 + 2.468 \times BLOOD_{EBW}$	0.09	4.15
	Bulls	$A_{BH} = 1.148 - 0.002 \times CD - 0.036 \times HIDE_{EBW}$		
Ash	Steers	$A_{BH} = 2.622 - 0.026 \times CD - 0.036 \times HIDE_{EBW}$	0.13	0.14
	Heifers	$A_{BH} = 1.759 - 0.013 \times CD - 0.036 \times HIDE_{EBW}$		
Ca		$Ca_{BH} = 0.026$	-	0.01
P		$P_{BH} = 0.034$	-	0.01
Na		$Na_{BH} = 0.196$	-	0.06
K		$K_{BH} = 0.099$	-	0.04
	Bulls	$Mg_{BH} = 0.0059 + 0.0000022 \times EBW$		
Mg	Steers	$Mg_{BH} = 0.0088 + 0.0000022 \times EBW$	0.10	0.003
	Heifers	$Mg_{BH} = 0.0072 + 0.0000022 \times EBW$		

[1] EE_{BH} = ether extract in blood + hide (%), CW = carcass weight (kg), $HIDE_{EBW}$ = percentage of hide weight in the EBW (%), CP_{BH} = protein in blood + hide (%), W_{BH} = water in blood + hide (%), A_{BH} = ashes in blood + hide (%), $BLOOD_{EBW}$ = percentage of blood in the EBW (%); CD = carcass dressing (%); Ca_{BH} = calcium in blood + hide (%), P_{BH} = phosphorus in blood + hide (%), Mg_{BH} = magnesium in blood + hide (%), Na_{BH} = sodium in blood + hide (%), K_{BH} = potassium in blood + hide (%) and EBW = empty body weight (kg); [2] RMSE = root mean square error.

Breed had no effect on the chemical composition of blood and hide, which is consistent with the fact that, biologically, there are no justifications for a possible difference (Table 14). The high CP content found (24.89%) agrees with the characteristics of these two body components, since hide is composed mainly of connective tissue, and the blood is composed by many proteins like albumin, prothrombin and globulin. These proteins represent much of the blood dry matter, as plasma (66% of the blood volume) contains 93% water (Verrastro, 2005).

The contents of EE in blood and hide were affected by carcass weight (CW), which may be related to the fact that heavier carcasses have higher fat content. These results suggest that a problem might be occurring during the slaughtering procedure. The database indicate that the greater the amount of carcass fat, the greater the amount of residual fat left in the hide after the skinning procedure. However, this type of error seems to be difficult to measure.

The levels of macrominerals in the blood and hide remained stable, except for Mg. Despite the variation observed, the use of the values suggested in Table 14 may be recommended because the content of minerals in hide and blood represent only about 5.6% of the total body minerals, as these compounds are concentrated mainly in bones. Therefore, the values obtained are a good estimate of the mineral composition of the blood plus hide.

With the exception of ether extract and water, the values obtained for the head and limbs composition had low variation (Table 15). These equations were more accurate than those for the blood and hide composition, as evidenced by their lower RMSE values. Thus, the equations presented in Table 15 are recommended for estimating head and limbs composition.

Table 15 - Equations used for estimating the chemical composition of the head and limbs together

Component	Gender	Genetic group	Equation[1]	r^2	RMSE[2]
Ether extract			EE_{HL} = 6.55 + 0.993 × VF	0.46	1.76
Protein	Bulls and heifers Steers		CP_{HL} = 9.930 + 0.0014 × EBW CP_{HL} = 6.072 + 0.0155 × EBW	0.02	2.50
Water			W_{HL} = 57.475 – 1.094 × VF	0.29	2.79
Ash			A_{HL} = 15.121	-	1.67
Ca			Ca_{HL} = 5.68	-	1.21
P		Nellore Crossbred	P_{HL} = 2.63 P_{HL} = 1.74 + 0.0022 × CW	0.13	0.40
Mg			Mg_{HL} = 0.087	-	0.02
Na			Na_{HL} = 0.226	-	0.07
K			K_{HL} = 0.095	-	0.02

[1] EE_{HL} = ether extract in the head plus limbs (%) VF = visceral fat (% of EBW), CP_{HL} = protein in the head plus limbs (%), EBW = empty body weight (kg), W_{HL} = water in the head plus limbs (%), A_{HL} = ashes in the head plus limbs (%), Ca_{HL} = calcium in the head plus limbs (%), P_{HL} = P in the head plus limbs (%), CW = carcass weight (kg), Mg_{HL} = magnesium in the head plus limbs (%), Na_{HL} = sodium in the head plus limbs (%) and K_{HL} = potassium in the head plus limbs (%); [2] RMSE = root mean square error.

The content of EE in head and limbs can be estimated from the amount of VF in the body, as EE increases with increasing visceral fat. The VF may indicate a possible increase of fat deposition in the body; such increases are also reflected in the composition of the head and limbs.

To estimate the percentage of CP in the head and limbs, EBW was the variable that was fitted to the model, and it showed a more pronounced effect for steers than for bulls and heifers (Table 15). The increase of CP in the head and limbs as a function of EBW was probably due to reduced water in the head, which was negatively correlated with the proportion of VF in the animal. This negative relationship between fat deposition and water has been extensively discussed in the literature (Brodie et al., 1949; Soberman et al., 1949; Kraybill et al., 1951, Wellington et al., 1954; Berg and Butterfield, 1976), and the results presented here corroborate it.

It was not possible to develop equations to estimate the macromineral content of the head and limbs, except for phosphorus. Thus, the calcium, magnesium, sodium and potassium contents can be represented by their averages in the EBW, which were 5.68, 0.087, 0.226 and 0.095%, respectively.

The differences found in the phosphorus content of the head and limbs of Nellore versus crossbred cattle were due to the database used. For the crossbred animals, the average value of phosphorus observed might have been because the crossbred animals available in the database were mostly finishing animals and were, therefore, at a stage where mineral deposition appeared to have ceased. As for the Nellore animals, there was a higher percentage of phosphorus in the head and limbs as a result of a higher CW, probably because there were animals of all ages in the database, and young animals had not yet ceased phosphorus deposition. As a result, the percentage of this macromineral increased with increasing CW, which increases with the growth of the animal for Nellore cattle.

The equations used for estimating the chemical composition of the organs and viscera are shown in Table 16. The EE content can be estimated by VF, consistent with the fact that most of the EE deposited in organs and viscera is present in the VF. The slope coefficient in the EE prediction equation for organs and viscera was higher for steers and heifers than for bulls, and this seems to be the result of greater EE deposition in the organs and viscera of steers and heifers than in bulls. This occurs because heifers and steers deposit more fat than bulls (NRC, 2000), which may result in increased fat deposits in the organs and viscera as well as in places that are not included in the VF.

Table 16 - Equations used for estimating the chemical composition of organs and viscera together

Component	Gender	Equation[1]	r^2	RMSE[2]
Ether extract	Bulls	$EE_{OV} = 9.37 + 5.00 \times VF$	0.58	10.06
	Steers and heifers	$EE_{OV} = 9.37 + 6.50 \times VF$		
Protein	Bulls	$CP_{OV} = 12.015$	-	2.26
	Steers	$CP_{OV} = 10.656$		
	Heifers	$CP_{OV} = 9.858$		
Water		$W_{OV} = 77.217 - 5.212 \times VF$	0.62	7.48
Ash		$A_{OV} = 2.693 - 0.039 \times OV_{EBW} - 0.022 \times CD$	0.13	0.25
Ca		$Ca_{OV} = 0.079$	-	0.05
P		$P_{OV} = 0.108$	-	0.05
Mg		$Mg_{OV} = 0.017$	-	0.03
Na	Nellore	$Na_{OV} = 0.134 - 0.0026 \times OV_{CPVZ}$	0.03	0.04
	Crossbred	$Na_{OV} = 0.134 - 0.0020 \times OV_{CPVZ}$		
K		$K_{OV} = 0.148$	-	0.05

[1] EE_{OV} = ether extract in the organs and viscera (%), VF = visceral fat (% of EBW), CP_{OV} = protein in the organs and viscera (%), W_{OV} = water in the organs and viscera (%), A_{OV} = ash in the organs and viscera (%), OV_{EBW} = ratio of the organs and viscera to EBW (%), CD = carcass dressing (%), Ca_{OV} = calcium in the organs and viscera (%), P_{OV} = phosphorus in the organs and viscera (%), Mg_{OV} = magnesium in the organs and viscera (%), Na_{OV} = sodium in the organs and viscera (%) and K $=_{OV}$ potassium in organs and viscera (%). [2] RMSE = root mean square error.

There were no effects observed in the variables tested for CP content of the organs and viscera, leading to the use of average values. We observed a gender effect for the mean value of CP in the organs and viscera, with a higher value for bulls, followed by steers and heifers. These values indicate a greater fat deposition in females and steers compared to bulls (NRC, 2000). This increasing in fat deposition leads to a decreasing in the proportion of protein in the organs and viscera. It is noteworthy, however, that average values for CP in the organs and viscera should be used with caution, since the organs and viscera represent about 15% of EBW, and there is great variability in the levels of protein in this body component (Table 16). Therefore, whenever possible it is better to grind organs and viscera together to directly determine their chemical composition.

The equation for estimating the water present in organs and viscera followed the inverse trend of the EE equation, with a lower proportion of water when VF increases.

Except for sodium, there was no effect of any variable on the mineral composition of organs and viscera, showing that its proportion normally remains constant despite the variability observed in the database used (Table 16). The observed effect for sodium had a low r^2 value and a low regression coefficient (0.0020 and 0.0026) for Nellore and crossbred cattle, respectively.

ULTRASONOGRAPHY FOR PREDICTING BODY COMPOSITION

Another tool that has great potential to be used in the near future for estimating the composition of the carcass and empty body of animals is ultrasound. Ultrasound has already been used in Brazil to determine rib eye area and subcutaneous fat thickness at 12^{th} rib and rump. When combined with animal weight, this information may allow the development of models to estimate carcass and empty body chemical composition.

Ultrasound measurements have been used to estimate body composition in live animals in research, since it is a noninvasive method (Williams, 2002). However, there is still lack of information in Brazil regarding ultrasound measures that can be used to predict body composition. This technique was primarily used in Brazil for the formation of more homogeneous in feedlot, because it allows to deduce the time at which the animals are optimally ready for slaughter from pre-determined body composition data (Luz e Silva et al., 2004).

Sainz (2004) has presented equations for predicting body energy from body weight (body energy = 820.378 + 4.56002 x shrunk body weight, r^2 = 51.6%, standard error of the estimate = 119.858) and from subcutaneous fat thickness, measured by ultrasound (body energy = 250.020 + 92.4978 x fat thickness, r^2 = 65.2%, standard error of estimate = 101.697). By grouping these two variables into one equation, there was an improvement in the precision and accuracy of the estimates (reflected in the increase in the coefficient of determination and reduction of the standard error of estimate): body energy = ─ 523 + 2.70 x shrunk body weight + 68.6 x fat thickness, r^2 = 78.9%, standard error of estimate = 80.12.

Chizzotti et al. (2008) gathered data from animals in Brazil to determine their body composition from measurements obtained by ultrasound. The database contained 123 animals (58 bulls, 26 steers and 39 heifers) selected from 11 studies, of which 88 were Nellore and 38 were Nellore x Angus.

The equations suggested by the authors explained much of the data variation (Table 17). The genetic background affected the proposed models, with the exception of ether extract in the carcass, for which a single equation was suggested.

Despite not having gone through an evaluation process yet, the use of these equations seems promising, as the use of ultrasound is relatively inexpensive and minimally invasive. Accordingly, more studies should be conducted so that adjustments of the existing models may provide broader use of the technique.

Table 17 - Predictive equations of carcass and empty body composition from subcutaneous fat thickness (SFT, mm) and empty body weight (EBW, kg)

Items	Genetic group	Equation [1]	R^2
Carcass fat (kg)	Nellore	Fat_{CARC} = - 32.09 + 2.09 x SFT + 0.2249 x EBW	0.77
	Crossbred	Fat_{CARC} = - 8.53 + 3.81 x SFT + 0,0919 x EBW	
Ether extract in carcass (kg)		EE_{CARC} = - 21.85 + 1.77 x SFT + 0.1551 × EBW	0.84
Ether extract in the empty body (kg)	Nellore	EE_{EBW} = - 47.26 + 2.82 x SFT + 0.2993 × EBW	0.87
	Crossbred	EE_{EBW} = - 23.65 + 4.27 x SFT + 0.1822 × EBW	
Empty body energy (Mcal)	Nellore	E_{EBW} = - 353.59 + 16.06 x SFT + 3.6856 × EBW	0.93
	Crossbred	E_{EBW} = - 171.79 + 38.29 x SFT + 2.6163 × EBW	

[1] Fat_{CARC} = carcass fat (kg), EE_{CARC} = ether extract in the carcass (kg), EE_{EBW} = ether extract in the empty body weight (kg), E_{EBW} = energy in the empty body weight (Mcal). Adapted from Chizzotti et al. (2008).

FINAL CONSIDERATIONS

The use of equations for predicting carcass and empty body weight composition can bring important benefits for researchers who require this information. The various alternatives presented here provide researchers with a choice of how best to conduct their experiments. However, more research is needed to validate or refine these equations.

Models that estimate the composition of non-carcass components reduce workloads and promote the economical use of resources for research that requires knowledge of the body composition of animals. Nevertheless, further research is needed evaluate these equations.

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