5

Prediction of body and carcass composition of beef cattle

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INTRODUCTION

The nutrients required by cattle depend on body composition of the animals. The methods utilized to predict body composition can be classified as direct and indirect. Direct methods consist in separation and dissection of all body components and further quantification of physical and chemical components. Thereby, experiments conducted using direct methods become extremely labor-intensive, slow, and expensive due to the loss of at least half of the carcass of each animal as well as lot of people and laboratory analyses involved. However, indirect methods predict body composition from simple parameters without the need of complete carcass dissection.

Several indirect methods have been developed around the world. A method used to estimate body water and ether extract (EE) from specific gravity was developed by Kraybill et al. (1952) and, during the 1990´s, was used by researchers in Brazil (Gonçalves et al., 1991; Peron et al., 1993; Lanna et al., 1995; Alleoni et al., 1997). However, this method did not result in adequate estimates for animals raised under Brazilian conditions (Lanna et al., 1995; Alleoni et al., 1997). Other techniques utilizing tools such as antipyrine, titrated water, N-acetyl-amine-antipyrine (Panaretto and Till, 1963), urea dilution (Preston and Kock, 1973) and ^{40}K (Clark et al., 1976) were not widely used in Brazil due to the complexity, high cost, lack of equipments, and/or lack of experience. In this context, the most utilized indirect method in Brazil is that proposed by Hankins and Howe (1946), which equations were developed to estimate cattle carcass composition based on composition of the section between the ninth and eleventh rib. This technique widely spread due to the ease of use and low cost involved. Several groups reported positive results when this technique was used (Silva, 2001; Henrique et al., 2003; Paulino et al., 2005a).

THE USE OF THE SECTION BETWEEN THE NINTH AND ELEVENTH RIB CUT HH SECTION

Studies during the 1920´s (Trowbridge and Haigh, 1921; Trowbridge and Haigh, 1922; Moulton, 1923; Lush, 1926) evaluated several carcass cuts to estimate carcass physical composition. The results led to the conclusion that the region of the ribs presented the best relationship with carcass composition. Then, based on these results, Hankins and Howe (1946) evaluated the use of cuts in the carcass of cattle to predict carcass physical and chemical composition developing a technique to obtain a sample of carcass between ninth and eleventh rib cut (HH section; Figure 5.1).

The section between ninth and eleventh ribs can be obtained considering a carcass hanging by transverse foramen located in the animal pelvis, where the cut between ninth and eleventh ribs is performed (Figure 5.1). The distance between the first and the last bone rib points is measured (distance between point A and B), and 61.5% of this distance is calculated (point C). The cut of this section might be performed in the point which a perpendicular line to rule crossed by point C (point D), as shown in the Figure 5.1.

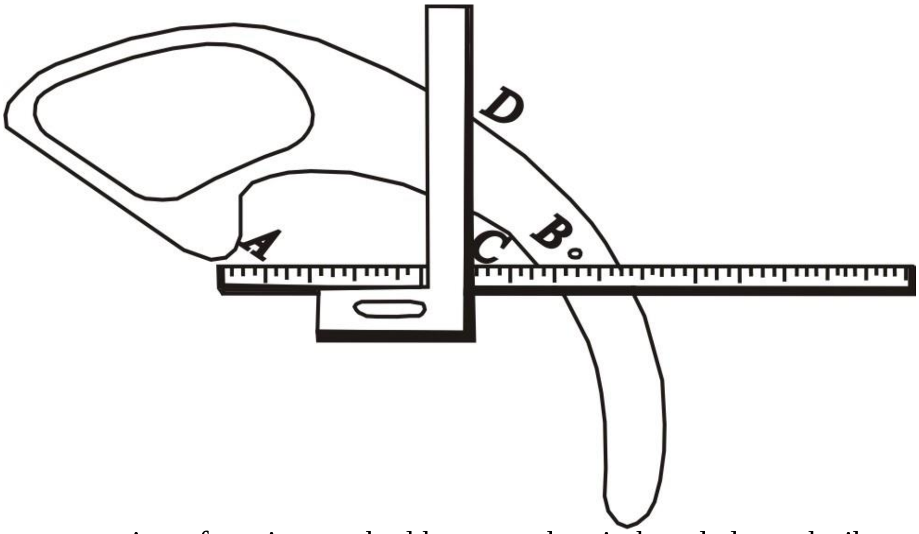

Figure 5.1 - Representation of section method between the ninth and eleventh rib cut developed by Hankins and Howe (1946).

CARCASS PHYSICAL AND CHEMICAL COMPOSITION AND EMPTY BODY CHEMICAL COMPOSITION

In the study developed by Hankins and Howe (1946), prediction equations for carcass physical and chemical composition were established. However, these equations were developed from data obtained from steers and heifers. Thus, equations for each sex and a general equation were defined (Table 5.1).

These equations have been widely used around the world and in Brazil due to the ease of obtaining HH section. Some studies (Cole et al., 1962; Powell and Huffman, 1973; Crouse and Dikeman, 1974; Nour and Thonney, 1994) aimed to evaluate these equations, however, presented distinct results. These differences may be related to fact that the prediction equations for chemical composition were estimated from soft tissue, while bone composition was not considered.

Some researchers have predicted the carcass chemical composition of beef cattle from the chemical composition of HH section (Peron et al., 1993; Jorge et al., 2000; Ferreira et al., 2001; Véras et al., 2001) by chemically analyzing samples of muscle, adipose, and bone tissues obtained from dissection of HH section and estimating carcass chemical composition. Nevertheless, carcass physical composition was estimated from the equations developed by Hankins and Howe (1946). Thereby, carcass chemical composition was estimated from data of chemical analyses obtained in samples of HH section, while body components was determined by the sum of carcass and non-carcass composition. As carcass is the main quantitative component of the empty body, the majority of these studies concluded that body chemical composition could be predicted from the chemical composition of HH section. However, other studies (Silva, 2001; Paulino et al., 2005a; Costa e Silva et al., 2013) reported that this premise could not be corrected, mainly in relation to EE content in the carcass.

Aiming to solve this problem, in the first edition of the Brazilian system – Nutrient Requirements for Zebu cattle (BR-CORTE; Valadares Filho et al., 2006), equations were developed to predict the carcass and empty body chemical composition of Zebu cattle from HH section. Only data from studies that evaluated chemical composition after the complete dissection of the half-carcass and chemical composition of the HH section were utilized. The database consisted of information from 66 animals from two studies (Paulino, 2002; Paulino, 2006; Table 5.2).

Table 5.1 - Prediction equations for physical and chemical carcass composition from composition of the section between ninth and eleventh rib cut proposed by Hankins and Howe (1946)

Item	Sex	Equation[1]
Carcass physical composition		
Fat, %	General	% Fcarc = 3.06 + 0.82 × % F_{HH}
	Steers	% Fcarc = 3.54 + 0.80 × % F_{HH}
	Heifers	% Fcarc = 3.14 + 0.83 × % F_{HH}
Muscle, %	General	% Mcarc = 15.56 + 0.81 × % M_{HH}
	Steers	% Mcarc = 16.08 + 0.80 × % M_{HH}
	Heifers	% Mcarc = 16.09 + 0.79 × % M_{HH}
Bone, %	General	% Bcarc = 4.30 + 0.61 ×% B_{HH}
	Steers	% Bcarc = 5.52 + 0.57 × % B_{HH}
	Heifers	% Bcarc = 6.88 + 0.44 × % B_{HH}
Carcass chemical composition		
Ether extract, %	General	% EEcarc = 2.82 + 0.77 × % EE_{HH}
	Steers	% EEcarc = 3.49 + 0.74 × % EE_{HH}
	Heifers	% EEcarc = 2.73 + 0.78 × % EE_{HH}
Crude protein, %	General	% CPcarc = 5.98 + 0.66 × % CP_{HH}
	Steers	% CPcarc = 6.19 + 0.65 × % CP_{HH}
	Heifers	% CPcarc = 5.64 + 0.69 × % CP_{HH}
Water, %	General	% Wcarc = 14.90 + 0.78 × % W_{HH}
	Steers	% Wcarc = 16.83 + 0.75 × % W_{HH}
	Heifers	% Wcarc = 14.28 + 0.78 × % W_{HH}

[1]Fcarc = fat in the carcass; F_{HH} = fat in the HH section; Mcarc = muscle in the carcass; M_{HH} = muscle in the HH section; Bcarc = bone in the carcass; B_{HH} = bone in the HH section; EEcarc = ether extract in the carcass; EE_{HH} = ether extract in the HH section; CPcarc = crude protein in the carcass; CP_{HH} = crude protein in the HH section; Wcarc = water in the carcass; W_{HH} = water in the HH section.

Table 5.2 - Prediction equations for chemical carcass and empty body composition of Zebu cattle from chemical composition of the section between ninth and eleventh rib cut proposed by the BR-CORTE (Valadares Filho et al., 2006)

Item	Equation[1]	Standard error	R^2
Carcass chemical composition			
Ether extract	% EEcarc = 4.96 + 0.54 ×% EE_{HH}	2.22	0.80
Crude protein	% CPcarc = 4.05 + 0.78 ×% CP_{HH}	1.00	0.72
Ash	% Acarc = 2.88 + 0.50 ×% A_{HH}	0.66	0.40
Water	% Wcarc = 34.97 + 0.45 ×% W_{HH}	1.94	0.66
Empty body chemical composition			
Ether extract	% EE_{EBW} = 4.56 + 0.60 ×% EE_{HH}	2.37	0.81
Crude protein	% CP_{EBW} = 4.96 + 0.76 ×% CP_{HH}	0.90	0.75
Ash	% A_{EBW} = 2.54 + 0.39 ×% A_{HH}	0.47	0.45
Water	% W_{EBW} = 31.42 + 0.51 ×% W_{HH}	1.94	0.71

[1]EEcarc = ether extract in the carcass; CPcarc = crude protein in the carcass; Acarc = ash in the carcass; Wcarc = water in the carcass; EE_{HH} = ether extract in the HH section; CP_{HH} = crude protein in the HH section; A_{HH} = ash in the HH section; W_{HH} = water in the HH section; EE_{EBW} = ether extract in the empty body composition; CP_{EBW} = crude protein in the empty body composition; A_{EBW} = ash in the empty body composition; W_{EBW} = water in the empty body composition.

In the first edition of the BR-CORTE (Valadares Filho et al., 2006), nutrient requirements were estimated based on complete dissection and sampling of the carcass from cattle used in the experiments. Moreover, this technique might be utilized until an adequate number of information was generated and, then, more comprehensive and representative equations could be developed. In this way, Marcondes et al. (2010; 2012) composed a new database with 247 animals from 6 experiments conducted in feedlot. Animals from this database were purebred Nellore cattle and their crossbred with Angus or Simmental. These authors evaluated the inclusion of new variables into models, as well as the effect of sex, study and breed, and, prediction equations for carcass physical and chemical composition and empty body chemical composition were developed (Table 5.3).

Table 5.3 - Description of data utilized by Marcondes et al. (2010; 2012) to develop equation for body composition of cattle from section between ninth and eleventh rib cut

Item	Mean	SD[1]	Maximum	Minimum
Empty body weight (EBW), kg	328	78.8	506	176
Carcass weight, kg	206	50.3	323	99.7
Organs + viscera, % EBW	15.3	1.60	21.8	12.2
Visceral fat[2], % EBW	4.60	1.60	8.80	1.40
Ether extract in the EBW, %	18.2	5.60	30.0	4.15
Crude protein in the EBW, %	17.6	1.62	23.4	12.9
Water in the EBW, %	58.5	4.27	71.4	49.1
Ether extract in the carcass, %	17.9	5.20	29.8	3.87
Crude protein in the carcass, %	17.3	1.93	28.5	12.4
Water in the carcass, %	58.0	3.91	73.5	43.9
Adipose tissue in the carcass, %	20.7	6.30	33.6	7.30
Muscle in the carcass, %	61.8	4.20	73.1	52.8
Bone in the carcass, %	17.5	3.00	28.1	12.6
Ether extract in the HH section, %	23.2	8.91	50.9	4.85
Crude protein in the HH section, %	16.7	2.07	24.0	11.4
Water in the HH section, %	52.8	6.53	67.6	29.3
Adipose tissue in the HH section, %	28.1	9.00	50.6	7.00
Muscle in the HH section, %	53.4	7.20	71.4	25.0
Bone in the HH section, %	18.7	3.90	32.7	11.4

[1]SD = standard deviation; [2]Visceral fat = mesenteric fat plus renal, pelvic, and cardiac fat.

The equations proposed by Marcondes et al. (2012) have already been utilized previously in the second edition of the BR-CORTE (Valadares Filho et al., 2010; Tables 5.4 and 5.5).

Table 5.4 - Prediction equations for the carcass physical and chemical composition and empty body chemical composition of Zebu and crossbred cattle from chemical composition of the section between ninth and eleventh rib cut proposed by Marcondes et al. (2010; 2012)

Variable	GG/Sex[1]	Equation[2]	R^2	RSME[3]
Carcass physical composition				
Fat[*]	-	$\% Fcarc = a + 0.30 \times \% F_{HH} + b \times \% VF$	0.79	3.01
Muscle	Nellore Nellore × Simmental	$\% Mcarc = 57.33 + 0.20 \times \% M_{HH} - 1.39 \times \% VF$	0.51	2.97
	Nellore × Angus	$\% Mcarc = 60.96 + 0.12 \times \% M_{HH} - 1.39 \times \% VF$		
Bone	Nellore Nellore × Simmental	$\% Bcarc = 29.26 + 0.30 \times \% B_{HH} - 0.21 \times HCY - 0.95 \times \% VF$	0.77	1.43
	Nellore × Angus	$\% Bcarc = 29.26 + 0.30 \times \% B_{HH} - 0.21 \times HCY - 1.01 \times \% VF$		
Carcass chemical composition				
EE	-	$\% EEcarc = 4.31 + 0.31 \times \% EE_{HH} + 1.37 \times \% VF$	0.83	2.13
CP	-	$\% CPcarc = 17.92 + 0.60 \times \% CP_{HH} - 0.17 \times HCY$	0.50	1.26
	Nellore	$\% Wcarc = 48.74 + 0.28 \times \% W_{HH} - 0.017 \times EBW$		
Water	Nellore × Angus	$\% Wcarc = 38.06 + 0.48 \times \% W_{HH} - 0.017 \times EBW$	0.67	2.27
	Nellore × Simmental	$\% Wcarc = 46.69 + 0.32 \times \% W_{HH} - 0.017 \times EBW$		
Empty body chemical composition				
	Bulls	$\% EE_{EBW} = 2.75 + 0.33 \times \% EE_{HH} + 1.80 \times \% VF$		
EE	Steers[**]	$\% EE_{EBW} = 1.84 + 0.33 \times \% EE_{HH} + 1.91 \times \% VF$	0.89	1.97
	Heifers	$\% EE_{EBW} = 4.77 + 0.33 \times \% EE_{HH} + 1.28 \times \% VF$		
CP	-	$\% CP_{EBW} = 10.78 + 0.47 \times \% CP_{HH} - 0.21 \times \% VF$	0.59	1.03
	Bulls	$\% W_{EBW} = 38.31 + 0.33 \times \% A_{HH} - 1.09 \times \% VF + 0.50 \times \% OV$		
Water	Steers[**]	$\% W_{EBW} = 45.67 + 0.25 \times \% A_{HH} - 1.89 \times \% VF + 0.50 \times \% OV$	0.82	1.96
	Heifers	$\% W_{EBW} = 31.61 + 0.47 \times \% A_{HH} - 1.06 \times \% VF + 0.50 \times \% OV$		

[1]GG = genetic group; [2]Fcarc = fat in the carcass; F_{HH} = fat in the HH section; Mcarc = muscle in the carcass; M_{HH} = muscle in the HH section; Bcarc = bone in the carcass; B_{HH} = bone in the HH section; EEcarc = ether extract in the carcass; EE_{HH} = ether extract in the HH section; EE_{EBW} = ether extract in the empty body; % VF = percentage of mesenteric fat plus renal, pelvic, and cardiac fat in the empty body; CPcarc = crude protein in the carcass; CP_{HH} = crude protein in the HH section; HCY = hot carcass yield (%); CP_{EBW} = crude protein in the empty body; Wcarc = water in the carcass; W_{HH} = water in the HH section; EBW = empty body weight; W_{EBW} = water in the empty body; % OV = percentage of organs and viscera in the empty body; [3]RSME = root square mean of error.
*There was effect of sex for intercept while there was interaction between sex and breed for the coefficient related to %VF where the deployment of this interaction can be seen in the Table 5.5.
**The new equations for Nellore x Angus steers are presented in the section "Evaluation of the equations proposed by Hankins and Howe (1946), BR-CORTE (2006) and BR-CORTE (2010)".

Table 5.5 - Deployment of the effect of sex on intercept and interaction between sex and breed on coefficient related to percentage of mesenteric fat plus renal, pelvic, and cardiac fat (VF)

Sex	Genetic group	Intercept	Coefficient related to VF
Bulls	Nellore	0.689	1.177
	Nellore × Angus		1.198
Steers	Nellore	5.259	0.379
	Nellore × Angus		0.430
	Nellore × Simental		0.740
Heifers	Nellore	0.471	1.532
	Nellore × Angus		1.981
	Nellore × Simental		2.338

According to Marcondes et al. (2012), the inclusion of new variables in models and considering the effect of genetic group and sex provided better estimates. Among the variables utilized, the most important inclusion was the mesenteric fat plus renal, pelvic, and cardiac fat (VF) in the prediction equations due to fat present in the carcass is the most variable component. The VF, together with other variables, could present a better understanding of the animal's metabolism. The VF was consisted by the physical separation of fat from mesentery added to renal, pelvic, and cardiac fat (Valadares Filho et al., 2010). The effect of feeding level on body composition has been discussed extensively in the literature (Prior et al., 1977; Ferrell et al., 1978; Nour et al., 1981; Williams et al., 1983; Nour and Thonney, 1987); thus, VF in the equations might be very important for applicability of them.

EVALUATION OF THE EQUATIONS PROPOSED BY HANKINS AND HOWE (1946), BR-CORTE (2006), AND BR-CORTE (2010)

Body composition of Zebu bulls and beef crossbred cattle (bulls and steers)

In Brazil, few studies have tried to evaluate the applicability of the equations proposed by Hankins and Howe (1946) for Zebu cattle and crosses with *Bos taurus* breeds. In this way, some researches (Lana et al., 1995; Silva, 2001; Paulino et al., 2005b; Costa e Silva et al., 2013; Fonseca et al., 2014) evaluated if the section between ninth and eleventh rib cut could estimate carcass and empty body composition and concluded that the equations developed by Hankins and Howe (1946) are not applicable for Zebu cattle and their crosses.

In relation to physical composition, Costa e Silva et al. (2013) concluded that the equations proposed by Marcondes et al. (2012) adequately estimate the physical composition of Nellore bulls. The authors do not recommend using the equations proposed by Hankins and Howe (1946). Moreover, Fonseca et al. (2014) concluded that the equations proposed by Marcondes et al. (2012) estimate adequately muscle and adipose tissue of F1 Nellore × Angus bulls and steers, although they reported that none of the equations estimated correctly the amount of bone for F1 Nellore × Angus cattle.

In the same way, some studies (Prados, 2012; Costa e Silva et al., 2013; Neves, 2013; Fonseca et al., 2014) evaluated whether the equations proposed by Hankins and Howe (1946), Valadares Filho et al. (2006, BR-CORTE) and Valadares Filho et al. (2010, BR-CORTE) correctly estimate the carcass and empty body chemical composition of Zebu cattle and their crosses. Costa e Silva et al. (2013) recommended that the equations proposed by Valadares Filho et al. (2006) and Hankins and Howe (1946) should not be utilized to estimate carcass and empty body composition of Nellore bulls, while the equations proposed by BR-CORTE (2010) presented accurate estimates.

Fonseca et al. (2014) utilized data from F1 Nellore × Angus bulls and steers and verified that the equations proposed by Marcondes et al. (2012) showed superior estimates, except for water in the empty body. As water is calculated by difference, this component is susceptible to the accumulation of errors from other analyses (Costa e Silva et al., 2013). Furthermore, Fonseca et al. (2014) observed that the equation proposed by Marcondes et al. (2012) for EE in the empty body was accurate and precise, mainly when sex was considered. For bulls, the equation was satisfatory and does not require adjustment, while for steers, the equation was not adequate for fatter animals.

Because the equation proposed by Marcondes et al. (2012) was not adjusted sufficiently to estimate EE and water in the empty body for beef crossbred steers, a new database was developed utilizing data from Marcondes et al. (2012) and Fonseca et al. (2014) to estimate EE. The same data were used by Marcondes et al. (2012) to estimate water in the empty body.

Thus, the estimates of EE and water in the empty body of beef crossbred steers were readjusted using the cross-validation procedure (Duchesne and MacGregor, 2001). For EE in the empty body, 20% of data from each experiment were randomly separated for validation, while for water, an independent experiment was utilized for validation of the equations.

$$\% EE_{EBW} = 2.797 + 0.289 \times \% EE_{HH} + 2.056 \times \% VF$$

$(R^2 = 0.84; RSME = 2.51)$

$$\% W_{EBW} = 30.77 + 0.48 \times \% W_{HH} - 1.07 \times \% VF + 0.50 \times \% OV$$

$(R^2 = 0.88; RSME = 2.42)$

Therefore, the inclusion of new variables such as VF and organs and viscera (OV) improved the estimates of carcass and empty body chemical composition for Zebu cattle and their crosses, which will allow future use of the equations proposed here instead of promoting complete dissection of the half-carcass. The use of these equations is recommended to estimate empty body composition and, as result, there will be decreasing on costs and labor of experiments conducted to estimate nutrient requirements of beef cattle (Costa e Silva et al., 2013).

Body composition of Zebu cattle (steers and heifers)

No previous study has evaluated the accuracy and precision of the equations suggested by Marcondes et al. (2012) for Zebu steers and heifers. Thereby, data collected from thesis of Costa e Silva (2015) which 32 Nellore heifers and 18 Nellore steers were utilized to evaluate if the equations estimate correctly carcass and empty body chemical composition (Table 5.6).

Table 5.6 - Description of data utilized to evaluate the equations for body composition of Nellore steers (*n* = 18) and heifers (*n* = 32)

Item	Mean	SD[1]	Maximum	Minimum
Steers				
Empty body weight, kg	168	39.5	260	109
Carcass weight, kg	101	24.5	160	65.4
Organs + viscera, % EBW	14.1	1.56	17.5	11.7
VF[2], % EBW	3.02	0.93	4.63	1.73
Ether extract in the EBW, %	9.83	1.60	12.7	7.52
Crude protein in the EBW, %	18.7	0.78	20.0	17.0
Water in the EBW, %	67.7	1.16	69.6	65.5
Ether extract in the carcass, %	10.6	1.55	13.4	7.55
Crude protein in the carcass, %	18.5	0.94	20.3	16.9
Water in the carcass, %	66.2	1.61	68.8	62.0
Ether extract in the HH section, %	12.2	2.69	17.4	6.06
Crude protein in the HH section, %	18.9	1.77	21.8	15.8
Water in the HH section, %	64.1	1.52	65.8	58.8
Heifers				
Empty body weight, kg	190	40.4	266	104
Carcass weight, kg	116	24.8	162	62.6
Organs + viscera, % EBW	14.8	0.99	16.81	13.1
VF[2], % EBW	3.93	0.88	5.83	1.65
Ether extract in the EBW, %	13.1	2.38	18.9	7.45
Crude protein in the EBW, %	18.5	0.75	20.4	17.1
Water in the EBW, %	64.9	2.49	70.0	60.4
Ether extract in the carcass, %	13.0	2.36	18.1	8.23
Crude protein in the carcass, %	18.5	0.90	21.3	16.6
Water in the carcass, %	64.3	2.59	69.0	59.5
Ether extract in the HH section, %	15.2	2.91	20.4	9.12
Crude protein in the HH section, %	17.5	1.52	20.1	14.3
Water in the HH section, %	62.7	1.73	67.1	59.9

[1]SD = standard deviation; [2]VF = mesenteric fat plus renal, pelvic, and cardiac fat.

Comparisons among equations were performed as proposed by Costa e Silva et al. (2013). We observed that the equations proposed by Hankins and Howe (1946), Valadares Filho et al. (2006) and Marcondes et al. (2012) correctly estimated the amount of crude protein (CP) in the carcass, while only the equations suggested by Marcondes et al. (2012) correctly estimate the amounts of EE and water in the carcass (Table 5.7).

For empty body, only equations proposed by Marcondes et al. (2012) and presented initially in the BR-CORTE (Valadares Filho et al., 2010), correctly estimated all components, while the equations proposed by Valadares Filho et al. (2006) presented inconsistencies on intercept and/or slope. So, they are not recommended to estimate body composition in Zebu steers and heifers (Table 5.8).

Table 5.7 - Means (kg) and descriptive statistics of the relationship between observed and predicted values of carcass chemical composition from growing Nellore steers and heifers

Item	Crude protein				Ether extract				Water			
	Obs[1]	HH	V06	V10	Obs	HH	V06	V10	Obs	HH	V06	V10
Mean	19.9	19.3	19.4	19.7	14.0	15.7	14.2	15.5	71.1	70.0	69.6	69.4
Standard deviation	4.36	3.79	3.75	3.78	5.61	5.47	4.57	5.41	14.9	15.43	15.6	15.0
Maximum	28.7	27.4	27.5	28.1	29.4	25.0	22.1	27.8	104	103	101	99.3
Minimum	11.9	11.8	11.8	12.0	4.94	6.19	6.28	5.93	42.9	41.7	40.8	41.2
R	-	0.94	0.92	0.95	-	0.92	0.93	0.94	-	0.99	0.99	0.99
CCC[2]	-	0.92	0.90	0.94	-	0.87	0.91	0.90	-	0.99	0.98	0.98
Regression												
Intercept												
Estimate	-	-0.96	-0.92	-1.75	-	-0.84	-2.29	-1.09	-	4.25	5.26	2.67
Standard error	-	1.17	1.33	1.05	-	0.97	0.96	0.86	-	1.47	1.39	1.43
P value[3]	-	0.42	0.49	0.10	-	0.39	0.02	0.21	-	0.006	0.0004	0.07
Slope												
Estimate	-	1.08	1.07	1.10	-	0.94	1.14	0.97	-	0.96	0.95	0.99
Standard error	-	0.06	0.07	0.05	-	0.06	0.06	0.05	-	0.02	0.02	0.02
P value[4]	-	0.19	0.29	0.07	-	0.32	0.03	0.58	-	0.04	0.008	0.49
MSE[5]	-	2.67	3.11	1.88	-	8.02	4.54	6.19	-	6.41	7.26	7.09
Mean bias	-	0.34	0.23	0.03	-	3.11	0.07	2.38	-	1.33	2.29	2.88
Systematic bias	-	0.09	0.07	0.13	-	0.10	0.42	0.02	-	0.46	0.69	0.04
Random error	-	2.24	2.80	1.71	-	4.81	4.05	3.79	-	4.62	4.27	4.17

[1]Obs – observed values; HH – values predicted by equations from Hankins and Howe (1946); V06 – values predicted by equations from Valadares Filho et al. (2006); V10 – values predicted by equations from Valadares Filho et al. (2010). [2]CCC – concordance correlation coefficient; [3]H_0: β_0=0. [4]H_0: β_1=1. [5]MSE = mean square error.

Table 5.8 - Means (kg) and descriptive statistics of the relationship between observed and predicted values of empty body chemical composition from growing Nellore steers and heifers

Item	Crude protein			Ether extract			Water		
	Obs[1]	V06	V10	Obs	V06	V10	Obs	V06	V10
Mean	33.7	33.7	33.4	22.1	24.0	25.2	117	113	113
Standard deviation	6.10	5.49	5.50	8.73	7.80	9.06	23.1	23.8	23.2
Maximum	46.8	45.9	45.7	41.6	37.5	42.6	171	165	158
Minimum	19.9	20.3	20.2	7.77	10.4	8.93	72.9	68.4	70.1
R	-	0.95	0.97	-	0.94	0.96	-	0.99	0.98
CCC[2]	-	0.94	0.96	-	0.91	0.91	-	0.98	0.97
Regression									
Intercept									
Estimate	-	-1.79	-2.24	-	-3.14	-1.34	-	8.25	6.69
Standard error	-	1.94	1.47	-	1.41	1.02	-	2.19	3.38
P value[3]	-	0.36	0.14	-	0.03	0.19	-	0.001	0.053
Slope									
Estimate	-	1.05	1.08	-	1.05	0.93	-	0.96	0.98
Standard error	-	0.06	0.04	-	0.06	0.04	-	0.02	0.03
P value[4]	-	0.35	0.09	-	0.36	0.06	-	0.06	0.40
MSE[5]	-	3.79	2.43	-	12.6	16.0	-	26.8	35.7
Mean bias	-	0.0002	0.08	-	3.65	10.1	-	17.1	15.0
Systematic bias	-	0.08	0.17	-	0.16	0.42	-	0.74	0.33
Random error	-	3.70	2.17	-	8.75	5.44	-	9.04	20.4

[1]Obs – observed values; V06 – values predicted by equations from Valadares Filho et al. (2006); V10 – values predicted by equations from Valadares Filho et al. (2010). [2]CCC – concordance correlation coefficient; [3]H_0: β_0=0. [4]H_0: β_1=1. [5]MSE = mean square error.

CARCASS AND EMPTY BODY CHEMICAL COMPOSITION FOR DAIRY CROSSBRED CATTLE

The equations to estimate carcass and empty body chemical composition in the last edition of the BR-CORTE (2010) were obtained from database of Zebu cattle (mainly Nellore) and beef crossbred cattle (crosses Nellore with beef breeds). Aiming to verify if these equations could be applicable to dairy crossbred cattle, Prados (2012), using ¼ Holstein × ¾ Zebu bulls, verified that CP in the empty body can be estimated adequately by the equation proposed by Valadares Filho et al. (2010) while EE and water in the empty body were correctly estimated by equations proposed by Valadares Filho et al. (2006). Neves (2013) evaluated Holstein × Zebu bulls and verified that equations proposed by Hankins and Howe (1946) estimated more accurately CP in the carcass and CP and water in the empty body. Also, this author concluded that equations proposed by Marcondes et al. (2012) were not able to estimate carcass and empty body chemical composition of Holstein × Zebu bulls.

Because the Holstein breed is included in the genotype, the prediction equations for carcass and empty body composition present problems of adjustment. Possibly, this might be due to database utilized by Marcondes et al. (2012) that is composed by Zebu (Nellore) and their crosses with beef breeds, such as Angus and Simmental, or so, breeds selected for beef production. Therefore, there is a need to develop new prediction equations for estimating the body composition of dairy crossbred cattle.

A database utilizing dairy crossbred cattle was developed from five experiments (Prados, 2012; Neves, 2013; Zanetti, 2014; Rodrigues, 2014; Silva, 2015). This database contained 180 observations, being 80 bulls, 56 steers, and 44 heifers (Table 5.9).

Table 5.9 - Description of data used to generate equation for body composition for dairy crossbred cattle from composition of the section between ninth and eleventh rib cut

Item	Mean	SD[1]	Maximum	Minimum
Empty body weight, kg	311	82.5	529	118
Carcass weight, kg	188	51.8	345	68.3
Non-carcass component weight, kg	117	29.4	224	50.0
Organs and viscera, kg	59.3	21.0	124	20.9
VF[2], kg	16.4	7.59	46.2	2.25
Crude protein in the HH section, %	17.2	2.22	25.5	8.70
Ether extract in the HH section, %	19.8	6.54	36.5	3.01
Ash in the HH section, %	5.24	2.36	10.9	0.68
Water in the HH section, %	57.4	6.13	74.3	42.3
Crude protein in the carcass, %	17.3	1.96	21.7	12.1
Ether extract in the carcass, %	16.5	4.24	30.6	7.47
Ash in the carcass, %	4.43	1.27	7.90	1.60
Water in the carcass, %	61.7	3.45	69.6	54.6
Crude protein in the empty body, %	17.8	1.63	21.5	14.7
Ether extract in the empty body, %	16.1	4.27	28.0	4.84
Ash in the empty body, %	3.90	1.11	6.47	1.51
Water in the empty body, %	62.0	3.75	71.8	52.7

[1]SD = standard deviation; [2]VF = mesenteric fat plus renal, pelvic, and cardiac fat.

From this database, the prediction equations for body composition of Holstein × Zebu cattle were established (Table 5.10). Using the cross validation procedure (Duchesne and MacGregor, 2001), the effect of animal was considered in the statistical analyses which allow the generation of only one equation for each evaluated component (CP, EE, and water). The equations presented good precision; however, we highlight that these equations were not validated with an independent database. However, we recommend the use of these equations because the cross validation procedure is adequate to be used in a small dataset.

Table 5.10 - Prediction equations for carcass and empty body chemical composition for dairy crossbred cattle

Item	Equations[1]	r^2
	Carcass chemical composition	
Ether extract	$\% EEcarc = 4.54 + 0.48 \times \% EE_{HH} + 0.12 \times \% OV$	0.66
Crude protein	$\% CPcarc = 18.38 + 0.16 \times \% CP_{HH} - 0.20 \times \% OV$	0.53
Water	$\% Wcarc = 55.67 - 0.21 \times \% W_{HH} - 0.021 \times EBW$	0.40
	Empty body chemical composition	
Ether extract	$\% EE_{EBW} = 3.53 + 0.34 \times \% EE_{HH} + 0.80 \times \% VF + 0.10 \times \% OV$	0.73
Crude protein	$\% CP_{EBW} = 19.92 + 0.086 \times \% CP_{HH} - 0.19 \times \% OV$	0.58
Water	$\% W_{EBW} = 53.02 + 0.17 \times \% W_{HH} - 1.28 \times \% VF + 0.27 \times \% OV$	0.47

[1]EEcarc = ether extract in the carcass; EE_{HH} = ether extract in the HH section; OV = percentage of organs and viscera in the empty body; PBcarc = crude protein in the carcass; VF = percentage of mesenteric fat plus renal, pelvic, and cardiac fat in the empty body; PB_{HH} = crude protein in the HH section; Wcarc = water in the carcass; A_{HH} = water in the HH section; EBW = empty body weight, kg; EE_{EBW} = ether extract in the empty body; CP_{EBW} = crude protein in the empty body; W_{EBW} = water in the empty body.

PREDICTION OF BODY MINERAL COMPOSITION

In the last edition of the BR-CORTE (2010), the prediction of body mineral composition was based on equations proposed by Marcondes et al. (2009) in which the composition of the section between the ninth and eleventh rib cut could be utilized as a possible estimator of empty body macromineral composition (calcium, phosphorus, sodium, potassium, and magnesium), using the data from two studies (Paulino, 2002; Marcondes, 2007; Table 5.11).

Table 5.11 - Prediction equations for macromineral composition (Ca, P, Mg, Na, and K) in the empty body for beef cattle from mineral composition of the section between ninth and eleventh rib cut (Adapted from Marcondes et al., 2009)

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

[1]Ca_{EBW} = calcium in the empty body; Ca_{HH} = calcium in the HH section; P_{EBW} = phosphorus in the empty body; P_{HH} = phosphorus in the HH section; Mg_{EBW} = magnesium in empty body; Mg_{HH} = magnesium in the HH section; Na_{EBW} = sodium in the empty body; Na_{HH} = sodium in the HH section; K_{EBW} = potassium in the empty body; K_{HH} = potassium in the HH section.

Marcondes et al. (2009) verified a high correlation between mineral components found in the HH section and those found in the empty body (Table 5.11). However, after evaluation of these equations, from data of Costa e Silva (2011), we observed that the equations generated by Marcondes et al. (2009) do not estimate correctly body macromineral composition (Ca, P, Mg, Na, and K) of Zebu cattle (Table 5.12).

Because the equations were not adjusted, a new database was developed from the two studies utilized by Marcondes et al. (2009) and the thesis of Costa e Silva (2015; Table 5.13) for Zebu cattle. Moreover, data of two studies (Marcondes, 2010; Souza, 2010) were utilized for the development of equations to estimate mineral composition for beef crossbred cattle and data of two studies (Rodrigues, 2014; Zanetti, 2014) to estimate mineral composition for dairy crossbred cattle.

Table 5.12 - Means (kg) and descriptive statistics of the relationship between observed and predicted values of mineral composition in the empty body of Nellore bulls

Item	Calcium		Phosphorus		Magnesium		Sodium		Potassium	
	Obs[1]	Predicted	Obs	Predicted	Obs	Predicted	Obs	Predicted	Obs	Predicted
Mean	4.37	3.00	2.83	2.91	0.12	0.14	0.42	0.39	0.60	0.41
Standard deviation	1.03	0.67	0.60	0.80	0.03	0.03	0.09	0.12	0.16	0.13
Maximum	7.15	4.66	4.25	5.47	0.17	0.20	0.61	0.68	0.90	0.71
Minimum	2.24	1.93	1.91	1.77	0.06	0.08	0.28	0.18	0.33	0.22
r	-	0.76	-	0.67	-	0.75	-	0.68	-	0.85
CCC[2]	-	0.31	-	0.64	-	0.62	-	0.62	-	0.46
Regression										
Intercept										
Estimate	-	0.85	-	1.35	-	0.03	-	0.22	-	0.19
Standard error	-	0.52	-	0.28	-	0.01	-	0.04	-	0.04
P-value[3]	-	0.11	-	< 0.001	-	0.03	-	< 0.001	-	< 0.001
Slope										
Estimate	-	1.17	-	0.51	-	0.63	-	0.53	-	1.01
Standard error	-	0.17	-	0.09	-	0.09	-	0.10	-	0.10
P-value[4]	-	0.32	-	< 0.001	-	< 0.001	-	< 0.001	-	0.92
MSE[5]	-	2.31	-	0.35	-	0.0009	-	0.009	-	0.043
Mean bias	-	1.86	-	0.01	-	0.0004	-	0.001	-	0.037
Systematic error	-	0.01	-	0.15	-	0.0000	-	0.003	-	0.000
Random error	-	0.44	-	0.19	-	0.0005	-	0.005	-	0.007

[1]Obs – observed values; [2]CCC – concordance correlation coefficient; [3]H_0: β_0=0. [4]H_0: β_1=1. [5]MSE = mean standard error.

Table 5.13 - Description of data used to generate equations to predict mineral composition of Zebu, beef crossbred, and dairy crossbred cattle

Item	Mean	SD[1]	Maximum	Minimum
Zebu cattle (n=133)				
Empty body weight, kg	272	102	549	104
Ash in the HH section, %	5.56	1.63	10.3	2.74
Calcium in the empty body, %	2.23	0.90	4.75	0.89
Phosphorus in the empty body, %	0.77	0.18	1.26	0.41
Magnesium in the empty body, %	0.04	0.01	0.08	0.02
Sodium in the empty body, %	0.12	0.02	0.18	0.08
Potassium in the empty body, %	0.17	0.02	0.26	0.10
Beef crossbred cattle (n=117)				
Empty body weight, kg	344	82.6	506	192
Ash in the HH section, %	6.29	1.29	9.68	1.79
Calcium in the empty body, %	1.51	0.29	3.19	1.04
Phosphorus in the empty body, %	0.72	0.12	0.98	0.48
Magnesium in the empty body, %	0.04	0.01	0.07	0.03
Sodium in the empty body, %	0.13	0.03	0.21	0.08
Potassium in the empty body, %	0.21	0.03	0.41	0.14
Dairy crossbred cattle (n=80)				
Empty body weight, kg	318	67.9	510	195
Ash in the HH section, %	3.90	2.55	8.06	0.68
Calcium in the empty body, %	1.32	0.25	1.77	0.59
Phosphorus in the empty body, %	0.71	0.18	1.10	0.20
Magnesium in the empty body, %	0.03	0.01	0.05	0.02
Sodium in the empty body, %	0.14	0.02	0.17	0.10
Potassium in the empty body, %	0.20	0.05	0.28	0.11

A meta-analysis was performed to evaluate body macromineral composition (Ca, P, Mg, Na, and K) for Zebu, beef crossbred, and dairy crossbred cattle (Table 5.14).

Table 5.14 - Prediction equations for macromineral composition (Ca, P, Mg, Na, and K) in the empty body for Zebu, beef crossbred, and dairy crossbred cattle

Item	Equation[1]	r^2
	Zebu cattle	
Calcium	$\% Ca_{EBW} = 1.4557 + 0.2362 \times \% ASH_{HH} – 0.00223 \times EBW$	0.80
Phosphorus	$\% P_{EBW} = 1.0068 - 0.00099 \times EBW$	0.10
Magnesium	$\% Mg_{EBW} = 0.02859 + 0.001721 \times \% ASH_{HH} – 0.00001 \times EBW$	0.54
Sodium	$\% Na_{EBW} = 0.1213 + 0.002116 \times \% ASH_{HH} – 0.00002 \times EBW$	0.51
Potassium	$\% K_{EBW} = 0.1942 + 0.000833 \times \% ASH_{HH} – 0.0001 \times EBW$	0.22
	Beef crossbred cattle	
Calcium	$\% Ca_{EBW} = 1.7028 + 0.04638 \times \% ASH_{HH} – 0.00142 \times EBW$	0.52
Phosphorus	$\% P_{EBW} = 0.4619 - 0.0404 \times \% ASH_{HH}$	0.49
Magnesium	$\% Mg_{EBW} = 0.02418 + 0.00196 \times \% ASH_{HH}$	0.34
Sodium	$\% Na_{EBW} = 0.1205 + 0.002747 \times \% ASH_{HH} – 0.00002 \times EBW$	0.56
Potassium	$\% K_{EBW} = 0.1636 + 0.007102 \times \% ASH_{HH}$	0.35
	Dairy crossbred cattle	
Calcium	$\% Ca_{EBW} = 1.2445 + 0.0506 \times \% ASH_{HH} - 0.00035 \times EBW$	0.58
Phosphorus	$\% P_{EBW} = 0.7279 + 0.0333 \times \% ASH_{HH} - 0.00048 \times EBW$	0.58
Magnesium	$\% Mg_{EBW} = 0.0406 - 0.00106 \times \% ASH_{HH}$	0.06
Sodium	$\% Na_{EBW} = 0.1454 + 0.00064 \times \% ASH_{HH}$	0.05
Potassium	$\% K_{EBW} = 0.1411 + 0.01478 \times \% ASH_{HH}$	0.79

[1]Ca_{EBW} = calcium in the empty body; ASH_{HH} = ash in the HH section; EBW = empty body weight (kg); P_{EBW} = phosphorus in the empty body; Mg_{EBW} = magnesium in the empty body; Na_{EBW} = sodium in the empty body; K_{EBW} = potassium in the empty body.

The r^2 estimates for the most of minerals as a function of genetic group were satisfactory. Nevertheless, the estimates of r^2 were close to zero for phosphorus and potassium in Zebu cattle, potassium in beef crossbred cattle, and magnesium and sodium in dairy crossbred cattle, showing that there is a tendency of constancy of this minerals in the body. However, we highlight that these equations will require validation to properly evaluate the effect of genetic group.

NON-CARCASS CHEMICAL COMPOSITION

Based on the equations proposed in the last edition of the BR-CORTE (2010; Table 5.4), the prediction equations for empty body chemical composition presented a better adjustment when compared with the equations for carcass chemical composition using the chemical composition of HH section as estimator. However, if the researcher makes the decision to utilize the equations for carcass chemical composition, or if there is a need to determine real carcass composition by dissection, the composition of other parts of the body (blood, hide, limbs, head, organs, and viscera) will need to be determined to ascertain empty body chemical composition.

The determination of non-carcass chemical composition implicates, necessarily, in greater cost, time, and labor, once there are at least 6 more samples (blood, hide, limbs, head, organs, and viscera) per animal that should be analyzed in laboratory. Carcass yield in relation to EBW may range from 60–65% (Costa et al., 2005; Missio et al., 2009), all non-carcass components, together, would represent from 35–40% EBW. Thus, the knowledge of non-carcass chemical composition is important due to its percentage of empty body composition.

Thus, Costa e Silva et al. (2012) evaluated the possibility of estimating chemical composition of blood, hide, limbs + head, and organs + viscera to decrease labor and experimental cost. These authors utilized a database with information from 335 animals to perform the evaluations, controlling for the effect of study and testing the effect of genetic group or sex on the composition of these non-carcass components. Chemical composition of each non-carcass component (blood, hide, limbs, head, organs, and viscera) could be estimated, and adjustment for each component would be necessary. However, this procedure would produce a large number of equations, which renders their use impractical. Then, to simplify the estimates, the non-carcass components were grouped (head + limbs, hide + blood, and organs + viscera) to decrease the number of equations and to facilitate their estimation.

Nevertheless, Costa e Silva et al. (2013) evaluated the accuracy of the prediction equations for non-carcass components, as described in the BR-CORTE (2010), and verified that, for hide + blood, only CP was correctly estimated; the equations to estimate EE and water presented problems with reproducibility and precision. In relation to head + limbs, any equation estimated correctly chemical composition. For organs + viscera, only EE was correctly estimated. Therefore, these authors concluded that new equations should be developed, or so, instead of dividing non-carcass components in three groups (hide + blood, head + limbs, and organs + viscera), the composition of these components might be analyzed together generating only one equation for each constituent, considering, thus, all non-carcass components as a unique pool. In this context, a database was developed from the composition of non-carcass components as depicted in 19 dissertations and/or theses: Moraes (2006), Souza (2009), Marcondes (2007), Marcondes (2010), Chizzotti (2007), Porto (2009), Gionbelli (2010), Paixão (2009), Paulino (2006), Machado (2009), Costa e Silva (2011), Costa e Silva (2015), Valente (2013), Fonseca (2014), Silva (2015), Prados (2012), Rodrigues (2013), Zanetti (2014), and Neves (2014). The database was composed by 505 animals, being 231 Zebu, 94 beef crossbred, and 180 dairy crossbred cattle; and 248 bulls, 134 steers, and 123 heifers (Table 5.15).

Table 5.15 - Description of data used to generate equations to predict non-carcass chemical composition of Zebu, beef crossbred, and dairy crossbred cattle (n = 505)

Item	Mean	SD[1]	Maximum	Minimum
Empty body weight, kg	302	92.2	549	80.7
Non-carcass component weight (NC), kg	112	34.0	224	31.6
Crude protein in the NC, kg	20.7	7.42	53.3	4.42
Ether extract in the NC, kg	20.4	12.5	69.9	1.89
Water in the NC, kg	65.4	17.5	134	22.5
Calcium in the NC, kg	0.80	0.62	3.57	0.04
Phosphorus in the NC, kg	0.31	0.26	1.76	0.02
Magnesium in the NC, g	16.5	8.28	50.0	2.37
Sodium in the NC, g	149	79.3	426	36.8
Potassium in the NC, g	134	62.8	324	31.4

[1]SD = standard deviation.

From the data obtained, prediction equations of non-carcass chemical composition were generated from the meta-analysis using the NLMIXED procedure, in which dependent variables were regressed as a function of EBW. Furthermore, effects of sex and genetic group were tested, where only sex was significant for all constituents, except phosphorus and magnesium (Tables 5.16 and 5.17).

Notably, these equations should be validated to verify that they correctly estimate non-carcass chemical composition for Zebu, beef crossbred and dairy crossbred cattle.

Table 5.16 - Prediction equations for non-carcass chemical composition for Zebu, beef crossbred, and dairy crossbred cattle in function of sex

Item	Sex	Equations
Crude protein	Bulls	$CP_{NC} = 0.1675 \times EBW^{0.8434}$
	Steers	$CP_{NC} = 0.5263 \times EBW^{0.6452}$
	Heifers	$CP_{NC} = 1.2411 \times EBW^{0.4921}$
Ether extract	Bulls	$EE_{NC} = 3.7171 \times \exp^{(0.004936 \times EBW)}$
	Steers	$EE_{NC} = 4.8911 \times \exp^{(0.004671 \times EBW)}$
	Heifers	$EE_{NC} = 3.5533 \times \exp^{(0.006199 \times EBW)}$
Water	Bulls	$W_{NC} = 1.5768 \times EBW^{0.6547}$
	Steers	$W_{NC} = 3.1486 \times EBW^{0.5242}$
	Heifers	$W_{NC} = 7.3003 \times EBW^{0.3865}$

[1]CP_{NC} = crude protein in the non-carcass components (kg); EBW = empty body weight (kg); EE_{NC} = ether extract in the non-carcass components (kg); W_{NC} = water in the non-carcass components (kg).

Table 5.17 - Prediction equations for macromineral composition of non-carcass components for Zebu, beef crossbred, and dairy crossbred cattle in function of sex

Item	Sex	Equations
Calcium	Bulls	$Ca_{NC} = 43.71 \times EBW^{0.3510}$
	Steers	$Ca_{NC} = 5.176 \times EBW^{0.8772}$
	Heifers	$Ca_{NC} = 69.36 \times EBW^{0.4342}$
Phosphorus	-	$P_{NC} = 2.262 \times EBW^{0.4522}$
Magnesium	-	$Mg_{NC} = 10.99 \times EBW^{0.1736}$
Sodium	Bulls	$Na_{NC} = 73.65 \times EBW^{0.1181}$
	Steers	$Na_{NC} = 3.264 \times EBW^{0.6916}$
	Heifers	$Na_{NC} = 23.04 \times EBW^{0.3544}$
Potassium	Bulls	$K_{NC} = 96.43 \times EBW^{0.0673}$
	Steers	$K_{NC} = 5.147 \times EBW^{0.5781}$
	Heifers	$K_{NC} = 31.54 \times EBW^{0.2821}$

[1]Ca_{NC} = calcium in the non-carcass components (g); EBW = empty body weight (kg); P_{NC} = phosphorus in the non-carcass components (g); Mg_{NC} = magnesium in the non-carcass components (g); Na_{NC} = sodium in the non-carcass components (g); K_{NC} = potassium in the non-carcass components (g).

RELATIONSHIP BETWEEN FAT-FREE DRY MATTER AND BODY COMPOSITION

Reid et al. (1955) suggested that body EE could be estimated from body water content. The authors also indicated that the protein/ash ratio in the body would be constant in fat-free dry matter, influenced only by the age of the animal. In this context, Marcondes et al. (2010) studied the relationship between fat-free dry matter and EBW composition utilizing a database with 272 animals. Marcondes et al. (2010) proposed the equation presented below to estimate body EE based on water content, following the model suggested by Reid et al. (1955). There was no effect of genetic group or sex on regression parameters, presenting a r^2 and RSME of 0.96 and 1.26, respectively.

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

where EE_{EBW} is the ether extract content in the empty body; W_{EBW} is the water percentage in the empty body; VF is the percentage of mesenteric fat, plus renal, pelvic, and cardiac fat in the empty body.

Knowing the proportion of the fat in the body, the protein concentration in the fat-free dry matter can be estimated as a function of the empty body mass. However, as opposed to Reid et al. (1955), that correlated protein/ash ratio with age, Marcondes et al. (2010) correlated this ratio with EBW, once age can be a relative measurement related to body composition, because different nutritional plans can cause different body weight at the same age, with consequent difference on body composition. Thus, the equation suggested by Marcondes et al. (2010), presented below, can be utilized alternatively. The ash percentage can be estimated as 100 – CP on the basis of fat-free dry matter.

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

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

NEW METHODS TO PREDICT BODY COMPOSITION OF CATTLE

Techniques that do not require animal slaughter to obtain body composition have been studied. They are useful for cattle sorting. In feedlot to reduce differences in relation to nutrient requirements of lots, in order to achieve carcass standardization.

Biometric measurements utilizing tape

Studies were developed (Fernandes et al., 2010; De Paula et al., 2013; Fonseca, 2013) aiming to predict body composition, main fat, from body measurements, known as biometric measurements. Fernandes et al. (2010) observed that the combination of different biometric measures (*in vivo* or *post-mortem*) can be important tools to estimate the amount of fat in the carcass and empty body of grazing animals. De Paula et al. (2013) suggested equations to estimate fat in different parts of the body, which divided as subcutaneous fat, intern fat, fat in the carcass, and fat in the empty body (Table 5.18).

Table 5.18 - Prediction equations for body fat from biometric measures using Nellore cattle

Item	Equations[1]	R^2	RSME
Subcutaneous Fat	$SF = 0.03 \times SBW - 0.099 \times BL + 0.052 \times WH$	0.97	0.94
Intern fat	$IF = 0.0405 \times SBW - 0.159 \times BPW$	0.98	1.26
Fat in the carcass	$F_{CARC} = 0.029 \times SBW + 25.941 \times F_{HH}$	0.99	2.41
Fat in the empty body	$F_{EBW} = 0.017 \times SBW + 1.184 \times F_{CARC}$	0.99	1.18

[1]SF = subcutaneous fat (kg); SBW = shrunk body weight (kg); BL = body length (cm); WH = wither height (cm); IF (Intern fat) = renal, pelvic, and cardiac fat (kg); BPW = bone pin width (cm); F_{CARC} = fat in the carcass (kg); F_{HH} = fat in the HH section (kg); F_{EBW} = fat in the empty body (kg). *Adapted from De Paula et al. (2013).*

However, even when biometric measurements are obtained (Fernandes et al., 2010; De Paula et al., 2013), there is a need for post-mortem measures, such as the amount of fat in the carcass and in the section between the ninth and eleventh rib cut in order to estimate the amount of fat in the empty body. Moreover, a problem found in biometric measurements is the need of measuring manually different points in the animal, and animal must being determined position. Due to the temperament of some animals, this technique becomes difficult to execute precisely.

Biometric measurements obtained from KINECT®

From the use of the Kinect® sensor (Microsoft, USA), an equipment composed by an infrared projector laser, an infrared camera, and a red, green, and blue (RGB) camera, new techniques have been used to estimate body composition without the need of animal slaughter. Thus, Monteiro (2015) evaluated several measures to predict body weight and body composition in Nellore and Angus bulls. The author correlated physical variables, such as body weight, and chemical variables, such as fat in the empty body, with areas generated by the Kinect®. From dorsal height and dorsal area (Figure 5.2) and breast width, this author generated indexes to estimate body weight and fat in the empty body (Table 5.19).

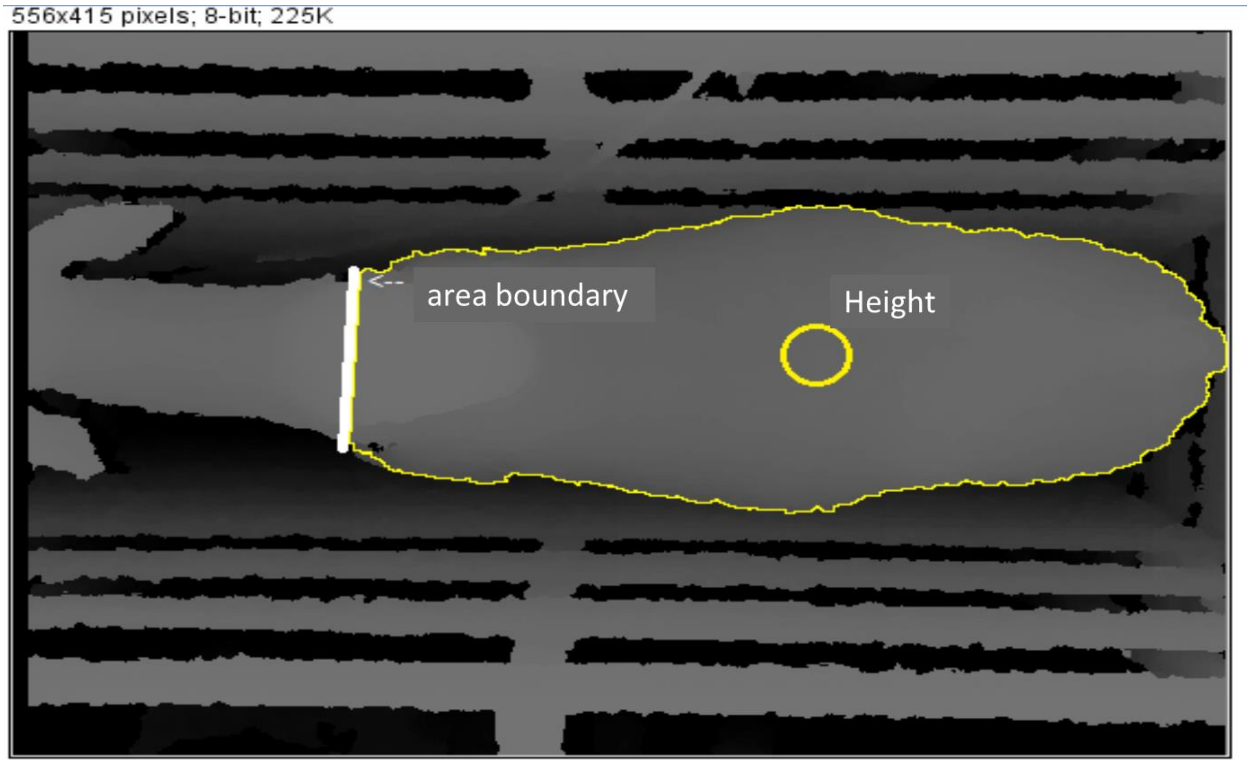

Figure 5.2 - Limit of the dorsal plan area obtained by three-dimensional image. Source: Monteiro (2015).

Table 5.19 - Description of indexes used in the equations

Index	Description[1]
I_1	Difference between dorsal height and the height whose breast width was measured
I_3	$(\text{dorsal area})^{0.75} / (\text{dorsal height})^2$
I_4	$(\text{breast width}) / (\text{dorsal area})^{1/2}$
I_5	$(\text{breast width})^2 \times \text{body length}$
I_6	$\text{dorsal area} / (\text{dorsal height}/1000)^2$

[1] height in mm, area in pixel^2, width and length in pixel.

From these indexes, animal body composition was determined by correlating the same with body fat and body weight (Table 5.20). However, more studies should be conducted to increase accuracy and to evaluate these equations using an independent database.

Table 5.20 - Regressions between body weight (BW), hot carcass weight (HCW), and body fat (BF) from body measurements obtained through digital image analyses in Nellore and Angus bulls

Model	Equations[1,2]	R^2	AIC	MSEP
	Body weight, kg			
1	$81.4 + 58.3 \times I_1 + 0.0000222 \times I_5 + 0.0310 \times I_3$	0.84	105.2	19.4
2	$164.6 + 0.0000278 \times I_5$	0.77	106.3	19.8
	Hot carcass weight, kg			
3	$74.8 + 0.0000141 \times I_5 + 0.0124 \times I_3$	0.83	87.8	15.4
4	$91.9 + 0.0000168 \times I_5$	0.80	88.3	16.5
	Body fat, % EBW			
5	$22.4 + 0.0319 \times BW - 6.46 \times I_1 - 28.2 \times I_4 - 118.2 \times I_6$	0.43	18.5	1.40

[1]The descriptions of the indexes are presented in the Table 5.19; [2]EBW = empty body weight, kg; BW = body weight.

Composition obtained from DXA

The technique of dual energy X-ray absorptiometry (DXA) becomes an alternative to carcass dissection to evaluate animal body composition. This method is the most utilized in human medicine aiming to evaluate the early reduction on bone mass and to evaluate body composition. It can thus be utilized without the need to dissect and chemically analyze the animal carcass. In this way, Prados et al. (2016) grouped a database with 116 observations, being 96 Nellore bulls and 20 Nellore × Angus bulls and developed equations to estimate the composition of the section between ninth and eleventh rib cut from the use of the equipment DXA (GE Lunar Prodigy Advance Dxa System, GE Healthcare, Madison, Wisconsin, USA). After scanning the section between the ninth and eleventh rib cut, these cuts were dissected and chemical composition was compared to parameters observed by DXA (Table 5.21).

Table 5.21 - Prediction equations for chemical composition of section between ninth and eleventh rib cut using dual-energy X-ray absorptiometry (DXA)

Variable[1]	Equations	R^2
Ether extract (EE)	$EE_{HH} = 122.40 + 1.12 \times F_{DXA}$	0.86
Fat free tissue (FF)	$FF_{HH} = 103.22 + 0.87 \times FF_{DXA}$	0.93
Lean tissue (LT)	$CP_{HH} = 37.08 + 0.91 \times LT_{DXA}$	0.95
Ash (A)	$A_{HH} = 18.72 + 1.02 \times BMC_{DXA}$	0.39

[1]EE_{HH} = ether extract in the HH section; F_{DXA} = fat measured by DXA; Fat free tissue = lean tissue added with ash content in the bone, FF_{HH} = fat free in the HH section (water + protein + ash); FF_{DXA} = fat free measured by DXA ($LT_{DXA} + BMC_{DXA}$); LT_{SC} = lean tissue in the HH section; LT_{DXA} = lean tissue measured by DXA; A_{HH} = ash in the HH section; BMC_{DXA} = bone mineral content measured by DXA; [2]All variables in grams. *(Adapted from Prados et al., 2016).*

Prados et al. (2016) evaluated the accuracy of these equations and concluded that they are accurate, representing a feasible and easy tool to predict the chemical composition of the section between the ninth and eleventh rib cut. Therefore, these equations are recommended to be used in Nellore and Nellore × Angus cattle. However, Prados et al. (2016) highlighted that more studies should be conducted aiming to evaluate its use to estimate carcass composition.

CONSIDERATIONS

After evaluation of the prediction equations for body composition, we recommend the use of the equations proposed by the BR-CORTE (2016) for Zebu and beef crossbred cattle as a replacement for carcass dissection, resulting in reduced costs and labor.

We expect that equations generated for dairy crossbred cattle can contribute for reduction of costs in experiments that aim to evaluate body composition of these animals.

Furthermore, the use of prediction equations for non-carcass components is an accurate approach. However, we highlight that more studies should be conducted to validate them.

New techniques, such as DXA and Kinect®, represent promising alternatives.

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