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Prediction of non-carcass components in cattle[1]

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ABSTRACT - This study was conducted to develop equations to predict chemical composition of head, limbs, hide and blood in cattle. A database containing 335 animals from 10 trials, with 221 Nellore, 38 Nellore-Simmental and 76 Nellore-Angus (96 steers, 118 heifers and 121 bulls) animals was used. Models were constructed to estimate water, ether extract (EE), crude protein (CP), ash and macrominerals (calcium, phosphorus, magnesium, sodium and potassium) in the non-carcass parts of cattle. A stepwise procedure was conducted to determine the most significant variables within each model. Subsequently, a random coefficient model was used to construct the equation using studies as random effect, and sex and breed as fixed effects. The visceral fat was the most important variable in the prediction models developed, affecting EE and water in head and limbs; head CP; and hide and blood water. Carcass dressing affected head EE and water and water in the limbs. Carcass weight had significant influence on head CP and hide EE; it was also affected by hide percentage in empty body weight (EBW). The percentage of OV in EBW influenced hide water. Lastly, EBW had influence only on hide sodium. Sex affected the EE of head and limbs. No breed effect was observed on any of the equations obtained. The estimation of the composition of head, limbs, hind and blood is possible and recommended, once they do not have great relevance to the estimation of EBW composition.

Key Words: blood, carcass, ether extract, hide, organs and viscera, protein

Introduction

Since the beginning of the 20th century, researchers such as Kleiber (1932) have tried to develop accurate and precise methods of estimating the body composition of cattle without having to dissect the entire body.

Several methods have been developed in order to directly estimate the empty body composition (Hopper, 1944; Kraybill et al., 1952; Panaretto & Till, 1963; Clark et al., 1976; Valadares Filho et al., 2006); however, most empirical models estimate only carcass composition should be more accurate than the body as a whole. In this sense, Valadares Filho et al. (2006) found better standard errors and coefficients of determination for the prediction equations of carcass composition in comparison with those of prediction of empty body weight composition.

Some researchers have developed models to predict the carcass composition (Hankins & Howe, 1946; Powell & Huffman, 1973; Crouse & Dikeman, 1974; Valadares Filho et al., 2006) aiming at greater accuracy at the estimates, or studying the development of the carcass composition individually. Therefore, when using equations to estimate carcass composition, but also needing information on body composition, it is also necessary to predict the composition of limbs, head, hides, blood and organs and viscera, although this procedure is more cumbersome.

In order to facilitate the estimate of the composition of non-carcass components, the objective of this study was to develop equations to predict the chemical composition of head, limbs, hides and blood using data from several research studies conducted in Brazil.

Material and Methods

A database was built using experimental results from 10 experiments, encompassing 335 animals, conducted at Universidade Federal de Viçosa, in which 221 animals were from the Nellore breed, 38 were crossbred Nellore-Simmental, and 76 were Nellore-Angus (96 heifers, 118 steers and 121 bulls) (Table 1).

All the experiments had the same slaughter procedures, which were preceded by 18 hours of fasting of solids and slaughter by stunning followed by bleeding through the jugular vein. Subsequently, the gastrointestinal tract was

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Table 1 - Description of experiments used to compose the database used to estimate the composition of non-components of the carcass in cattle

Reference	Genetic group	Gender	n	EBW	
				Min	Max
Chizzotti (2007)	Nellore × Angus	Steers	12	201	415
		Heifers	12	175	386
		Bulls	12	218	449
Souza (2010)	Nellore × Angus	Heifers	20	210	442
	Nellore		19	192	368
	Nellore × Simmental		18	201	415
Gionbelli (2010)	Nellore	Heifers	24	108	318
Marcondes (2007)	Nellore	Steers	9	225	388
		Heifers	9	198	353
		Bulls	9	221	433
Marcondes (2009)	Nellore × Angus	Steers	20	285	506
	Nellore		20	246	447
	Nellore × Simmental		20	275	492
Paulino (2006)	Nellore	Steers	15	253	391
		Heifers	16	225	397
		Bulls	16	283	438
Machado (2009)	Nellore	Bulls	15	228	335
Moraes (2006)	Nellore	Bulls	13	118	314
Paixão (2008)	Nellore	Bulls	21	235	387
Porto (2009)	Nellore	Bulls	35	145	436

EBW - empty body weight; n - number; Min - minimum; Max - maximum.

washed and weighed along with all the other body parts to compose the empty body weight (EBW). Visceral fat was computed as the KPH fat added to the mesentery fat. Carcasses were then taken to a cooling chamber (1-4 ºC) for 18 hours and completely dissected into meat, fat and bones. Head was separated at the joint of the occipital bone with the atlas, whereas forelimbs were separated at the Humeroradial joint and hindlimbs were separated at the tibiofemoral joint (Kapandji, 2000). Head plus one fore and one hind limb were sampled (at least of one animal per treatment) and dissected into soft tissue, bones and hides. Samples of all parts (organs and viscera, hides, blood, soft tissue of the head and limbs, bones of the head and limbs, meat + fat and bones of the carcass) were sampled after defatting and ground in a ball mill. Crude protein (CP), ether extract (EE) and ash were analyzed in these processed samples; water was obtained by the difference. Analyses of macrominerals calcium, phosphorus, sodium, potassium and magnesium were also carried out. No data from macrominerals were obtained from Paulino (2006) and Machado (2009), since they did not conduct such analyses in their study.

Models were constructed to estimate the percentage of EE, CP, water, ash, sodium, potassium, phosphorus, calcium and magnesium of hides (HID_{EE}, HID_{CP}, HID_{W}, HID_{A}, HID_{Na}, HID_{K}, HID_{P}, HID_{Ca} and HID_{Mg}, respectively), blood (BLD_{EE}, BLD_{CP}, BLD_{W}, BLD_{A}, BLD_{Na}, BLD_{K}, BLD_{P}, BLD_{Ca} and BLD_{Mg}, respectively) (Table 2), head ($HEAD_{EE}$, $HEAD_{CP}$, $HEAD_{W}$, $HEAD_{A}$, $HEAD_{Na}$, $HEAD_{K}$, $HEAD_{P}$, $HEAD_{Ca}$ and $HEAD_{Mg}$, respectively) and limbs (LIM_{EE}, LIM_{CP}, LIM_{W}, LIM_{A}, LIM_{Na}, LIM_{K}, LIM_{P}, LIM_{Ca} and LIM_{Mg}, respectively) (Table 3).

Regression analyses were performed initially through a stepwise procedure (SAS 9.1), in which variables EBW, percentage of organs and viscera in the EBW (POV), percentage of visceral fat in the EBW (VF), cold carcass

Table 2 - Description of data to develop the prediction equations for chemical composition of hide and blood of cattle

Composition	n	Mean (g/kg)	SD	Minimum (g/kg)	Maximum (g/kg)
			Hide		
g/kg EBW	335	108.20	1.05	72.47	146.30
Ether extract	335	76.10	4.77	3.03	258.01
Crude protein	335	270.07	4.90	132.71	363.46
Water	335	647.41	5.25	496.13	756.74
Ash	335	5.47	0.17	1.66	16.32
Sodium	273	1.68	0.06	0.23	2.73
Potassium	273	1.08	0.06	0.39	2.28
Phosphorus	273	0.42	0.02	0.13	1.16
Calcium	273	0.37	0.02	0.11	1.00
Magnesium	273	0.08	0.00	0.02	0.16
			Blood		
g/kg EBW	335	37.52	0.53	24.86	55.93
Ether extract	335	1.44	0.13	0.01	8.97
Crude protein	335	189.30	2.23	125.00	237.82
Water	335	798.86	2.06	749.73	852.50
Ash	335	8.17	0.35	3.66	21.21
Sodium	273	2.76	0.12	1.36	6.16
Potassium	273	0.44	0.02	0.19	1.01
Phosphorus	273	0.19	0.01	0.09	0.37
Calcium	273	0.24	0.02	0.03	0.78
Magnesium	273	0.04	0.00	0.01	0.08

n - number; SD - standard deviation.

Table 3 - Description of data to develop the prediction equation for chemical composition for head and limbs of cattle

Composition	n	Mean (g/kg)	SD	Minimum (g/kg)	Maximum (g/kg)
			Head		
g/kg EBW	144	39.25	0.62	27.69	57.39
Ether extract	144	99.15	2.89	40.01	162.74
Crude protein	144	186.18	1.30	157.91	218.85
Water	144	588.27	3.71	507.95	685.99
Ash	144	124.59	1.84	85.51	204.86
Sodium	126	2.25	0.08	0.59	3.31
Potassium	126	1.15	0.03	0.34	1.61
Phosphorus	126	19.18	0.72	0.55	39.88
Calcium	126	44.40	1.34	0.37	69.35
Magnesium	126	0.81	0.02	0.03	1.25
			Limbs		
g/kg EBW	144	14.41	0.72	5.95	48.44
Ether extract	144	118.44	2.61	63.79	210.09
Crude protein	144	243.80	2.90	166.32	313.82
Water	144	441.25	3.97	330.50	553.03
Ash	144	192.42	2.92	125.23	263.21
Sodium	126	2.87	0.08	1.22	4.55
Potassium	126	0.67	0.02	0.38	1.13
Phosphorus	126	31.32	0.90	15.89	67.63
Calcium	126	73.90	1.45	39.51	111.22
Magnesium	126	1.00	0.04	0.12	1.99

n - number; SD - stanrdard deviation.

weight (CCW) and cold carcass yield in relation to EBW (CCY) were suggested in the model to estimate the compositions described above; those which reached a significance degree of at least 5% were chosen.

Subsequently, a model of random coefficients was used to identify fixed and random effects by means of PROC MIXED of SAS (Statistical Analysis System, version 9.1). Several structures of variance and covariance were analyzed, and those which presented the lowest Akaike information criterion (AIC) were selected. The degrees of freedom of the tests were adjusted utilizing the option Kenward-Roger. Outliers were identified and excluded from the dataset when the Student residue was higher than |2.0|. Fixed or variable effects which did not reach significance level of 0.05 as well as the random ones that did not reach at least 0.20 of significance were removed from the model.

Results and Discussion

Visceral fat and CCY were defined as variables indispensable to the determination of $HEAD_{EE}$. The regression model had variable gender affecting CCY ($P<0.001$); however, no difference between steers and heifers ($P = 0.724$) was verified. Also no influence of genetic group was verified on any of the regression parameters ($P>0.05$), also no influence of gender was verified on the intercept ($P = 0.146$) or VF ($P = 0.239$). There was study effect for VF and CCY. The equation that estimates $HEAD_{EE}$ is:

Steers and heifers $HEAD_{EE}(\%) = -6.19 + 0.80 \times VF + 0.22 \times CCY$

Bulls $HEAD_{EE}(\%) = -6.19 + 0.80 \times VF + 0.19 \times CCY$

Five outliers were verified, and the covariance structures which presented best adjustment were UN and ARH(1), with AIC of 518.5, r^2 of 0.591 and root mean squared error (RMSE) of 1.92%. However, taking that the variability of $HEAD_{EE}$ is high (CV = 20%), it is hard to obtain a more precise model, even with a big amount of data such as those of the present study.

Both VF and CCY increase when the animal reaches maturity, so the inclusion of these variables in the model could indicate a maturation process of the animal, with consequent increase in the EE deposition rate.

Visceral fat and CCW were the variables determined by stepwise to estimate $HEAD_{CP}$. No effect of genetic group or gender was identified on any of the regression parameters ($P>0.05$). The random variable only had effect on the intercept ($P = 0.039$). Thus, a general equation for $HEAD_{CP}$ was obtained.

$$HEAD_{CP}(\%) = 18.62 - 0.22 \times VF + 0.0058 \times CCW$$

Five outliers were identified in the database for $HEAD_{CP}$ and the structures of covariance VC and UN had similar behavior, with AIC of 386.6. The regression had an r^2 of 13.2 and RMSE of 1.25%; however, since $HEAD_{CP}$ is practically constant, a lower r^2 was expected, even with low variation in the data (CV = 6.67%). Besides, one can consider that the inclusion of VF and CCW serve as fine tuning in the equation.

Through the equation above, it can be observed that there was a negative relation between VF and $HEAD_{CP}$, probably due to the dilution effect provoked by the excess of maturity previously explained, in which there is an increase in the deposition of EE, diluting the other components present in the head.

The model which described the concentration of water in the head ($HEAD_W$) had VF and CCY as discriminatory variables. No effect of genetic group or gender was observed on the regression parameters ($P>0.05$), and study effect was only observed for the intercept ($P = 0.031$); therefore, a general equation was obtained to generate $HEAD_W$:

$$HEAD_W(\%) = 89.89 - 0.54 \times VF - 0.47 \times CCY$$

Three outliers were identified on the database and structures VC and UN were those which obtained best AIC value (603.4). The r^2 of the regression was 0.259 and RMSE was 3.27%, showing that the precision of the equation was not high, although it had good accuracy.

It can be observed that the equation which determines $HEAD_W$ is a reflection of that which determines $HEAD_{EE}$, for it is known that there is a replacement of water by ether extract as the animal grows. None of the variable studied presented correlation with $HEAD_A$ according to the stepwise ($P>0.05$). Also, no effects of genetic group or gender were observed on the $HEAD_A$ average; however, a study effect was observed ($P<0.001$). Thus, a mean value of 0.1267 grams per kg head was obtained.

The analysis of ash is one of the analyses with largest source of errors, likely due to low mineral concentrations observed in the samples. Therefore, there was a considerable variation in this component (CV = 14.79%) and RMSE of 1.84%. On the other hand, since the concentrations of these constituents are low, errors associated to the utilization of a mean value have little impact on the final estimate of ash in the body.

None of the proportions of minerals in the head was affected by the discriminatory variables suggested by the stepwise (Table 4). Also there was no effect of genetic group or gender for any of the five minerals assessed; however, there was study effect ($P>0.20$) in all of them. Therefore, mean values of 2.20 grams of sodium, 1.11 g of potassium, 18.25 g of phosphorus, 42.61 g of calcium and 0.76 g of magnesium per kg of head were suggested.

The concentration of minerals is highly variable (Table 4), with all the coefficients of variation above 20%. This variable is higher than that found for ash (15%); therefore, it is possible that part of it is due to errors associated to the analyses of these minerals. The concentration of these minerals, as well as for ash, is low in the head, in which the obtainment of these concentrations would be, theoretically, subject to greater errors.

Limb composition had LIM_{EE} affected by VF. Genetic group did not affect the intercept ($P = 0.538$), or VF ($P = 0.491$); however, the gender affected both the intercept ($P<0.001$) and VF ($P<0.001$). Steers and heifers did not differ from each other ($P = 0.150$), both were different from bulls ($P<0.001$); therefore, one equation was obtained for these genders, and another for bulls.

Steers and heifers $LIM_{EE} = 10.65 + 0.35 \times VF$

Bulls $LIM_{EE} = 5.51 + 1.65 \times VF$

Only three outliers were found, and the covariance structures VC and UN were those which had best adjustment, with AIC of 509.0. The model had r^2 of 0.47 and RMSE of 1.78%, demonstrating good adjustment and accuracy.

Carcass weight affected LIM_{CP}; however, there was no effect of genetic group or gender on the intercept (P values of 0.118 and 0.797, respectively) or on CCW (P values of 0.237 and 0.851, respectively). Study effect was also verified on the intercept ($P = 0.025$). Thus, the general equation was obtained to determine LIM_{CP}:

$LIM_{CP} = 23.29 + 0.008 \times CCW$

Six outliers were identified and once again VC and UN were the covariance structures with greatest adjustment (AIC = 587.9). The r^2 of the regression was only 0.085; however, the low RMSE (2.78) (Figure 1), which the equation had good adjustment, but the low value of the CCW coefficient led to low r^2, indicating that LIM_{CP} is almost constant, corrected by a fine tuning performed by CCW.

The inclusion of CCW in the model also becomes necessary because, possibly, heavier animals need a structure in terms of stronger tendons and bones, in order to support the higher CCW, although no result was found in the literature to support this hypothesis.

Just like for $HEAD_W$, LIM_W was affected by both CCY and VF. Also, there was no effect of genetic group or gender on any of the coefficients ($P>0.05$), but there was study effect on the regression intercept ($P = 0.034$). The equation obtained was:

$LIM_W = 74.62 - 0.87 \times VF - 0.43 \times CCY$

Table 4 - Equations for prediction of head and limbs mineral composition in cattle

Mineral	Equation	AIC	RMSE	CV (%)
		Head		
Sodium	$HEAD_{Na} = 0.22$	−557.10	0.08	34.01
Potassium	$HEAD_K = 0.11$	−726.20	0.03	21.72
Phosphorus	$HEAD_P = 1.83$	72.50	0.72	37.51
Calcium	$HEAD_{Ca} = 4.26$	226.30	1.34	30.23
Magnesium	$HEAD_{Mg} = 0.08$	−697.30	0.02	29.10
		Limbs		
Sodium	$LIM_{Na} = 0.30$	−412.00	0.08	27.21
Potassium	$LIM_K = 0.06$	−783.40	0.02	24.70
Phosphorus	$LIM_P = 3.30$	218.00	0.90	28.72
Calcium	$LIM_{Ca} = 7.52$	389.40	1.45	19.68
Magnesium	$LIM_{Mg} = 0.10$	−558.70	0.04	38.48

AIC - Akaike information criterion; RMSE - root mean squared error; CV - coefficient of variation.

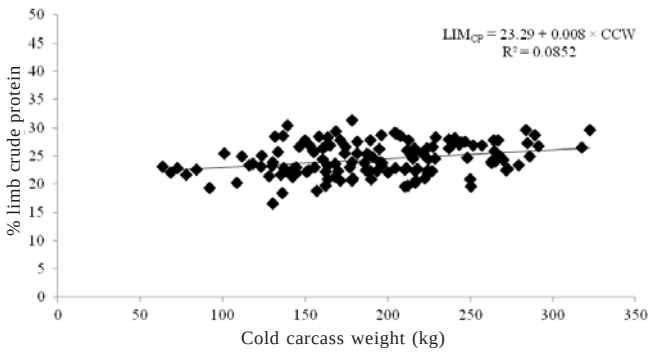

Figure 1 - Relationship between limb crude protein (%) and the cold carcass weight in cattle.

Eight data were removed as outliers and the AIC of the model was 595.6 (VC and UN). The equation had r^2 of 0.347 and RMSE of 3.29. In spite of the eight discrepant data, the equation seemed to have good adjustment and accuracy, which can also be confirmed by the low CV (7.49%).

The outlying variables of the model suggest once more a replacement of water by the ether extract when the animal grows, for higher values of VF and CCY are obtained with bigger animals.

As occurred with the head composition, none of the suggested variables had significant correlation with LIM_A (P>0.05); also, there was no effect of genetic group or gender on the composition. On the other hand, LIM_A was affected by the study effect (P = 0.307), and a mean value of 188.8 g LIM_A per kg of limb was estimated, with RMSE of 2.92 and AIC of 646.5. This variable also had a considerable variation (CV = 15.17%), probably caused by a problem at its obtainment, as discussed previously.

For the composition of minerals in the limbs, very similar behavior to those found in the head was found. There was no effect of any of the variables studied to estimate these components (P>0.05), in addition to the lack of effect from genetic group and gender for any mineral (P>0.05). There was study effect on all the minerals (P>0.05), showing once more that there is still big need for the development of an easy and standardized method for the evaluation of macrominerals with more precise results than those presented in this study.

Limbs presented average composition of 2.96 g of sodium, 0.61 g of potassium, 32.97 g of phosphorus, 75.16 g of calcium and 0.98 g of magnesium per kg of limbs. It is believed that the use of mean values for limbs and head are satisfactory to aid in the estimate of body composition of cattle, once they represent a small portion of the body of the animal (between 38.0 and 84.0 g/kg EBW).

The composition of hides had CCW and EBW_{HID} as determinant factors of HID_{EE}. No effect of gender or genetic group was verified on any of the coefficients of the equation (P<0.05), but study effect was shown for the intercept and CCW. Therefore, one single equation was obtained:

$$HID_{EE} = -6.76 + 0.035 \times CCW + 0.675 \times EBW_{HID}$$

Nineteen data were identified as outliers, and the model had AIC of 1735.3, r^2 of 0.264 and RMSE of 4.10. When the animal is bigger and more mature, the EE concentration is greater. Such fact can also be associated to problems at animal skinning, for when it is heavier and/or fatter, there is a big chance that part of the fat pertaining to the carcass remain stuck to the hides during the procedure. However, this type of error is hard to be measured.

For the protein, VF was the variable which presented moderate influence on HID_{CP} (P = 0.089). Because of the dilution factor with the problem of hide removal, the variable was kept in the model to contribute with the adjustment of the equation. No effect of genetic group or gender was observed on HID_{CP}; however, there was study effect on the intercept (P = 0.027) and on the VF coefficient (P = 0.070).

$$HID_{CP} = 27.90 - 0.37 \times VF$$

Twelve data were discarded as outliers and the equation had an r^2 of 0.054; however, this low value of r^2 is associated to the low slope of the line (Figure 2) rather than the worse model adjustment. The AIC value of the equation was 1317.1 and RMSE was 4.83%. Disregarding the VF in the model, the mean value, considering only the random effect of the study in the model, would be 269 g of CP per kg hide.

The water present in the hides had a negative relation with VF, which can be associated, once more, to the direct relation between fat in the carcass and VF, whereas when the relation with OV is observed, the relationship is already positive. The explanation for this fact seems not to be very clear, although it can be linked to the greater proportion of water or lower proportion of fat in the OV when the animal is young, and consequent diminishing of this content as the animal grows, occurring in the same manner as in hides.

There was no effect of genetic group or gender (P>0.05) on HID_W, and there was study effect only on the intercept (P = 0.055) and on VF (P = 0.087), so one single equation was adjusted:

$$HID_W = 58.37 - 1.34 \times VF + 0.89 \times OV.$$

Fifteen data were discarded as outliers, and the equation had r^2 of 0.277, RMSE of 4.51% and AIC of 1553.6, showing good model adjustment.

None of the variables was highly correlated with HID_A; also, there was no effect of genetic group or gender on the average estimated (P>0.05); however, it was affected by the

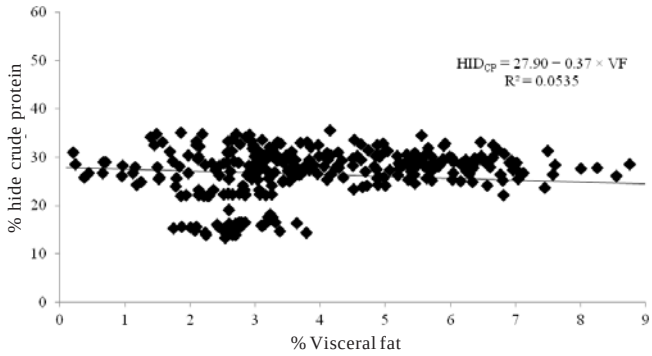

Figure 2 - Relationship between crude protein in the hides (HID_{CP}, %) and the percentage of visceral fat (%) in cattle.

random effect (P = 0.019). The estimate of HID_A was 6.3 g of HID_A per kg hides, and this model had AIC of – 450.9 and RMSE of 0.17. The high variation observed again for the ash (CV = 31.29%) can be one of the reasons for the low correlations found for this variable, in addition to the low mean value of ash presented by the hides, which hampers the analysis and increases the proportional error.

The concentration of macrominerals in the hides presented problems, especially due to the high variation observed (CV between 36.26 and 57.53%). However, it is believed that such fact occurred mainly due to the low proportions of these minerals commonly found in the hides. Another factor that contributes to this is the previously-mentioned problem with the determinations of these macrominerals in laboratory, in which the proportional error to the amount found in the tissue is large.

However, even having the knowledge of the high errors associated to these variables, the values presented in this study is highly recommended (Table 5), for the minerals present in the hides represent very little of the total found in the body, since they are concentrated mainly in the bones. Therefore, the values cited can bring a good estimate, of significantly lower value than the traditional methods (obtainment through laboratory analyses) and without compromising the final estimate of their concentration in the empty body.

Blood presented a stable EE concentration, which was not affected by any of the variables suggested by stepwise. Also, no effect of genetic group or gender was verified on BLD_{EE} (P>0.05); nevertheless, there was study effect on the variable (P = 0.018), which may also indicate problems in the obtainment of the EE of samples.

The mean value of BLD_{EE} obtained by the model was 1.8 g of BLD_{EE} per kg blood, with AIC of –831.2 and RMSE of 0.13. The biggest problem observed for this variable was the high CV of 89.54%, probably caused by its low concentration. However, considering an animal of 320 kg EBW, with 11.5% EE (36.8 kg), it would have about 3.75% blood (12 kg). This blood, according to the average obtained in this study, would represent a total of 21.6 g EE, which therefore does not justify the expenditures necessary for a more precise determination of BLD_{EE}.

The stepwise procedure determined the inclusion of VF as a variable discriminating BLD_{CP}. No information in the literature was found to explain this positive relation; however, r^2 of 0.35 and CV of 9.49% indicate a fair adjustment; therefore, further study is necessary for the responses herein presented to be better understood. No effect of genetic group or gender was found on BLD_{CP} (P>0.05); however, there was study effect on the regression intercept (P = 0.025), which is presented below:

$$BLD_{CP} = 16.47 + 0.59 \times VF$$

Fourteen data were verified as outliers, and the model had AIC of 969.5 and RMSE of 1.80. The good adjustment of the equation presented also indicates the non-necessity for getting this component through laboratory methods, even though it had concentration significantly higher than that presented for BLD_{EE}.

The analyses of BLD_W showed that it had been affected by VF, and this correlation was negative. None of the coefficients was affected by genetic group or gender (P>0.05); however, both the intercept (P = 0.043) and VF (P = 0.144) were affected by study effect. The final equation was defined as:

$$BLD_W = 82.08 - 0.54 \times VF$$

Fifteen data were excluded as outliers, and the model had AIC of 965.5, r^2 of 0.324 and RMSE of 1.70. The model had a quite satisfactory adjustment, especially considering that there was a little variation in the data (CV = 2.12%). The inclusion of VF seems to have contributed once again to improvement in the adjustment of the regression, although the explanation for such fact is not evident. It is possible

Table 5 - Equations for prediction hide and blood mineral composition in cattle

Mineral	Equation	AIC	RMSE	R^2	CV (%)
		Hide			
Sodium	$HID_{Na} = 0.16 + 0.00004 \times EBW$	– 1327.20	0.061	0.057	36.26
Potassium	$HID_K = 0.10$	– 1499.50	0.059	-	54.62
Phosphorus	$HID_P = 0.04$	– 1796.20	0.024	-	57.53
Calcium	$HID_{Ca} = 0.03$	– 1839.90	0.021	-	55.93
Magnesium	$HID_{Mg} = 0.013 - 0.00008 \times CCY$	– 2655.80	0.003	0.100	36.84
		Blood			
Sodium	$BLD_{Na} = 0.29$	– 1069.60	0.116	-	41.98
Potassium	$BLD_K = 0.05$	– 1766.10	0.020	-	46.11
Phosphorus	$BLD_P = 0.02$	– 2233.90	0.005	-	26.21
Calcium	$BLD_{Ca} = 0.02$	– 2023.20	0.015	-	62.66
Magnesium	$BLD_{Mg} = 0.004$	– 3014.90	0.002	-	35.11

AIC - Akaike information criterion; RMSE - root mean squared error; CV - coefficient of variation; EBW - empty body weight.

that the greater metabolic level (caused by a greater concentration of energy in the diet, reflected by VF) promotes an increase in the content of protein-based hormones such as insulin, elevating the CP contents, and consequently, increasing the blood density.

None of the variables studied had effect on BLD_A, which demonstrates that it has a constant concentration. These results are consistent, once due to the electrolytic balance of the body, there are mechanisms for the amount of circulating minerals to remain stable.

Also there was no effect of gender or genetic group on BLD_A ($P>0.05$), although study effect ($P = 0.023$) was observed. This effect is probably more associated to problems in the laboratorial methods of obtaining ash.

The mean value obtained by the model was 8.29 g of ash per kg blood, with AIC of – 416.9 and RMSE of 0.35. One experiment of these analyses was excluded (Moraes, 2006), because the data had Student residue superior to |2.0|; however, no other outlier was identified.

Analyses of macrominerals showed similar behavior to those observed for limbs and head, and all of them had constant concentration in the blood. Once more, there was no effect of genetic group or gender on the compositions studied ($P>0.05$); nevertheless, there was study effect on all of them ($P<0.20$). The averages obtained by the models were 2.86 g of sodium, 0.45 g of potassium, 0.19 g of phosphorus, 0.19 g of calcium and 0.04 g of magnesium per kg of blood.

Considerable variation was also observed in the data, especially for calcium ($P = 0.6266$), which might have contributed to the results found. However, it is believed that this variation does not affect the final estimate of macromineral composition in the body, for only a small part of it is located in the blood. As observed for ash, a constant concentration of macrominerals in the blood is coherent, once it contributes to the chemostatic balance of the body.

Overall, the elements analyzed in this study have a not very relevant influence on the final determination of the body composition, for they would represent between 170 and 250 g per kg EBW and present little variation in their composition. The rest of the amount is represented by the OV and carcass, which have a much more malleable composition, and are affected by diet, genetic group and/or gender.

Visceral fat had a major role in several equations, indicating a specific metabolic status of fat concentration in the body. Marcondes et al. (2010) had already detected this important role of this variable in the determination of the composition of carcass or empty body.

Conclusions

The estimation of the composition of limbs, head, hides and blood is possible and recommended, once they do not represent a great part of the empty body weight, minimally affecting its final composition. The models herein presented showed fair adjustment, caused by the high variation of the data analyzed.

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