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Relationships of Body Composition and Fat Partition with Body Condition Score in Serra da Estrela Ewes

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ABSTRACT: Twenty eight non-lactating and non-pregnant adult Serra da Estrela ewes, ranging in body condition score (BCS) from 1 to 4 were used to study the relationships between BCS, live weight (LW), body composition and fat partition. Ewes were slaughtered and their kidney knob and channel fat (KKCF), sternal fat (STF) and omental plus mesenteric fat (OMF) were separated and weighed. Left sides of carcasses as well as the respective lumbar joints were then dissected into muscle, bone and subcutaneous (SCF) and intermuscular fat (IMF). The relationship between LW and BCS was studied using data from 1,396 observations on 63 ewes from the same flock and it was found to be linear. Regression analysis was also used to describe the relationships among BCS and/or LW and weights (kg) and percentages in empty body weight (EBW) of dissected tissues. The prediction of weights and percentages in EBW of total fat (TF) and of all fat depots afforded by BCS was better than that provided by LW. Only the weight of muscle and the percentage of bone in the EBW were more efficiently predicted by LW than by BCS. IMF represented the largest fat depot with a BCS of 1 and 2, whereas SCF was the most important site of fat deposition with a BCS of 3 and 4. Allometric coefficients for each fat depot in TF suggest that the fat deposition order in ewes from this breed is: IMF, OMF, SCF and KKCF. Results demonstrate that BCS is a better predictor than LW of body reserves in this breed and that LJ is a suitable anatomical region to evaluate BCS. (**Key Words** : Body Condition Score, Body Composition, Sheep, Fat Partition)

INTRODUCTION

It is well recognized that, under farm conditions, body condition score (BCS) is an important tool to assess the adequacy of feeding programs, particularly in production systems where the availability of feeds are not constant. Ewes' BCS, first outlined by Jefferies (1961), was adapted by Russel et al. (1969) and tested by these authors in the Scottish Blackface breed. In most studies BCS demonstrate to provide a better prediction of body composition than live weight (LW) (Russel et al., 1969; Teixeira et al., 1989; Sanson et al., 1993) but Frutos et al. (1997) found that LW was more accurate to estimate body composition and fat depots in Churra breed. Between-breed differences in body size and fat partition (Russel et al., 1968 and 1969; Taylor et al., 1989) can possibly explain those contradictory results. Therefore, studies on each breed are needed in order to determine which of those parameters are more accurate for the evaluation of body reserves.

Lumbar joint (LJ), which is handled to assess BCS, was studied by others authors in order to predict the body composition of ewes (Delfa et al., 1989; Frutos et al., 1997) and goats (Amaro, 1990), as well as sternal fat in goats (Santucci and Maestrini, 1985; Morand-Fehr et al., 1989; Amaro and Caldeira, 1991).

The experiment reported here was designed to study the accuracy of BCS, LW, composition of LJ, and sternal fat to estimate body reserves, as well as to characterize fat partition in different BCS, in the Portuguese sheep breed Serra da Estrela, the top sheep dairy breed in Portugal.

MATERIALS AND METHODS

Twenty-eight non-pregnant, non-lactating, adult ewes of mixed ages from Serra da Estrela breed, were drawn from the experimental flock of Estação Zootécnica Nacional and randomly allocated in two groups which were fed with the same diet (mixture of corn silage and corn gluten) but at two different levels, 30% and 200% of maintenance

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Table 1. Means, standard deviations and extreme values of live weight in each half score of body condition score (BCS)

BCS	n	Live weight (kg)		
		Mean±SD	Minimum	Maximum
0.5	6	26.40±4.41	19.0	30.0
1	26	31.30±5.09	21.0	40.0
1.5	68	36.57±6.03	24.0	53.0
2	107	42.01±5.64	27.0	54.0
2.5	180	46.48±6.08	34.0	60.5
3	52	51.47±6.79	30.0	69.0
3.5	83	56.96±8.04	41.0	75.5
4	42	62.99±7.05	48.0	78.0
4.5	4	68.75±2.87	66.5	72.5

requirements (Agricultural Research Council, 1980), in order to bring them into different BCS. Ewes were housed in two large indoor pens with free access to water and trace mineralized salt during all the experiment. BCS was evaluated by two assessors using the Russel et al. (1969) technique and recorded weekly along with LW. When they attained the prescribed BCS: 1, 2, 3 and 4, ewes were slaughtered, after a 24 h fasting period.

Kidney knob and channel fat (KKCF), sternal fat (STF) and omental plus mesenteric fat (OMF) were separated and weighed. After 24-48 h at 0°C, left sides of carcasses as well as the respective lumbar joints (LJ) (Delfa et al., 1989) were dissected into muscle, bone and subcutaneous (SCF) and intermuscular fat (IMF), which weights were recorded.

The effect of BCS on LW was also studied on a larger sample: 1396 observations on 63 non-lactating, non-pregnant, adult ewes from the same flock as the experimental animals. All BCS and LW assessments were conducted between 9:00 and 10:00 h, before the ewes go out to pasture.

Statistical analysis was performed with the GLM procedure of SAS (SAS Institute, 2003) using the following models:

To evaluate the effect of BCS on: (i) LW, (ii) empty body weight (EBW) and (iii) dissected components

$$Y_{ij} = \mu + BCS_i + e_{ij}$$

To evaluate the effects of: (i) BCS on LW, (ii) BCS or LW on dissected components, (iii) dissected components of LJ on the same components in carcasses, and (iv) STF on TF, SF and muscle

$$Y_{ij} = \mu + b_1 \times (A_i) + e_{ij}$$

To evaluate if any improvement was achieved on the prediction of dissected components of carcass using simultaneously LW and BCS

$$Y_{ijk} = \mu + b_1 \times (BCS_i) + b_2 \times (LW_j) + e_{ijk}$$

To compute allometric coefficient (Huxley, 1932) for each fat depot:

$$\log \text{(fat depot)} = \mu + b_1 \times \log \text{(total fat)} + e_{ij}$$

Table 2. Means and standard errors of age, live weight (LW) and empty body weight (EBW) and of dissected components of half carcasses

Variable	Body condition score				SE
	1	2	3	4	
n	7	7	7	7	
Age (years)	7.00	9.86	7.43	8.00	0.796
LW (kg)	34.04^a	45.63^b	51.11^b	62.03^c	2.04
EBW (kg)	27.84^a	36.45^b	44.15^c	56.49^d	1.91
Muscle (kg)	7.227^a	10.498^b	11.373^{bc}	13.869^c	0.685
Bone (kg)	3.605	3.662	3.870	3.776	0.186
SCF (kg)	0.427^a	1.937^b	3.953^c	6.930^d	0.348
IMF (kg)	0.769^a	2.247^b	3.361^c	5.785^d	0.245
OMF (kg)	0.361^a	1.796^{ab}	3.169^b	5.183^c	0.369
KKCF (kg)	0.184^a	0.747^{ab}	1.450^b	2.749^c	0.181
STF (kg)	0.016^a	0.038^a	0.086^b	0.133^c	0.011
TF (kg)	1.741^a	6.727^b	11.933^c	20.646^d	0.886
Muscle/EBW (%)	25.74	28.84	25.65	24.48	0.83
Bone/EBW (%)	13.12^c	10.10^b	8.90^{ab}	6.74^a	0.60
SCF/EBW (%)	1.52^a	5.43^b	8.93^c	12.16^d	0.56
IMF/EBW (%)	2.75^a	6.25^b	7.62^b	10.25^c	0.47
OMF/EBW (%)	1.30^{ab}	5.01^b	7.20^{bc}	9.12^c	0.73
KKCF/EBW (%)	0.64^a	2.08^a	3.62^b	4.82^b	0.37
STF/EBW (%)	0.06^a	0.10^a	0.19^b	0.23^b	0.002
TF/EBW (%)	6.21^a	18.77^b	27.36^c	36.35^d	1.49

Means in the same line with different superscripts differ significantly ($p<0.01$).

SCF: subcutaneous fat, IMF: intermuscular fat, OMF: omental plus mesenteric fat, KKCF: kidney knob and channel fat, STF: sternal fat and TF: total fat.

Table 3. Prediction equations for estimating carcass components weights from body condition score (BCS) and live weight (LW)

Variable	Regression equation	R^2	RSD
$\log_{10}$ (muscle+1)	$0.914+0.409 \log_{10}$ BCS**	0.67	0.071
$\log_{10}$ (muscle+1)	$-0.683+1.041 \log_{10}$ LW**	0.93	0.032
Bone	$3.599+0.374 \log_{10}$ BCS ^{ns}	0.03	0.457
$\log_{10}$ bone	0.522+0.00008 LW ^{ns}	0.05	0.045
$\log_{10}$ (TF+1)	$0.428+1.473 \log_{10}$ BCS**	0.94	0.083
TF	-18.644+0.600 LW**	0.85	2.945
$\log_{10}$ SCF	$-0.373+2.021 \log_{10}$ BCS**	0.94	0.118
$\log_{10}$ SCF	$-6.553+4.116 \log_{10}$ LW**	0.84	0.195
$\log_{10}$ (IMF+1)	$-0.185+1.420 \log_{10}$ (BCS+1)**	0.92	0.063
$\log_{10}$ (IMF+1)	$-2.770+1.978 \log_{10}$ (LW+1)**	0.85	0.089
$\log_{10}$ OMF	$-0.434+1.930 \log_{10}$ BCS**	0.89	0.161
$\log_{10}$ OMF	$-6.261+3.886 \log_{10}$ LW**	0.77	0.228
$\log_{10}$ KKCF	$-0.785+2.000 \log_{10}$ BCS**	0.89	0.164
$\log_{10}$ KKCF	$-6.871+4.056 \log_{10}$ LW**	0.79	0.228
$\log_{10}$ STF	$-2.581+2.422 \log_{10}$ (BCS+1)**	0.81	0.182
$\log_{10}$ STF	$-6.919+3.331 \log_{10}$ (LW+1)**	0.73	0.217

RSD: Residual SD; ** $p<0.01$, ^{ns} $p>0.05$.

TF: toal fat, SCF: subcutaneous fat, IMF: itermuscular fat, OMF: omental plus mesenteric fat, KKCF: kidney knob and channel fat, STF: sternal fat.

Table 4. Prediction equations for estimating carcass components expressed as percentages of empty body weight (EBW) from body condition score (BCS) and live weight (LW)

Variable	Regression equation	R2	RSD
Muscle/EBW	27.92-0.069 BCS ^{ns}	0.09	1.604
Muscle/EBW	26.75-0.001 LW ^{ns}	0.00	1.614
Bone/EBW	$17.71-15.380 \log_{10}$ (BCS+1)**	0.70	1.251
Bone/EBW	$48.97-23.490 \log_{10}$ LW**	0.81	1.114
TF/EBW	$-16.59+74.580 \log_{10}$ (BCS +1)**	0.90	1.962
TF/EBW	$-141.45+97.380 \log_{10}$ (LW+1)**	0.73	2.512
SCF/EBW	-1.84+3.540 BCS**	0.89	1.201
SCF/EBW	-8.50+0.030 LW**	0.75	1.481
IMF/EBW	$-2.64+18.010 \log_{10}$ (BCS+1)**	0.83	1.116
IMF/EBW	$-32.83+23.540 \log_{10}$ (LW+1)**	0.68	1.316
OMF/EBW	$-4.49+19.530 \log_{10}$ (BCS+1)**	0.72	1.364
OMF/EBW	$-35.79+24.800 \log_{10}$ LW**	0.58	1.514
KKCF/EBW	-0.07+1.410 BCS**	0.75	0.976
KKCF/EBW	-3.08+0.010 LW**	0.57	1.116
STF/EBW	-0.0004+0.006 BCS**	0.64	0.000
STF/EBW	-0.01+0.00005 LW**	0.52	0.000

RSD: Residual SD; ** $p<0.01$, ^{ns} $p>0.05$.

TF: total fat, SCF: subcutaneous fat, IMF: intermuscular fat, OMF: omental plus mesenteric fat, KKCF: kidney knob and channel fat, STF: sternal fat.

For all the variables studied, the variance homogeneity was tested beforehand and those showing deviation from normal distribution were subjected to $\log_{10}$ or $\log_{10}$ (y+1) transformation (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Means, standard deviations and extreme values of LW in each half score of BCS (Table 1) show that, even in non-lactating and non-pregnant animals, ewes with a similar LW can exhibit very different BCS or, in other words, ewes scoring the same BCS may have very different LW. This can probably be justified by different body sizes of ewes in this breed and/or variation in gastrointestinal contents, which are some of the most important factors that make LW difficult to interpret in ruminants (Russel et al., 1971; Hossamo et al., 1986; Jarrige, 1988).

The regression equation between LW and BCS shows that LW increases 11.00 kg per unit change in BCS (LW = 20.893+11.002 BCS (R2 0.66, RSD 6.551, SE_b 0.213). This result is similar to those observed by Russel et al. (1969), Teixeira et al. (1989) and Sanson et al. (1993, with a 1 to 9 scores scale), for Scottish Blackface, Aragonesa and Western-range ewes, respectively, but is greater than those recorded by Peart (1970), MLC (1983), Caldeira and Portugal (1991), Oregui et al. (1991) and Frutos et al. (1997), in different sheep breeds. Differences were also explained by different body sizes and/or gastrointestinal contents and perhaps by the subjectivity of BCS evaluation (Evans, 1978).

Table 5. Correlation coefficients among body condition score (BCS), live weight (LW) and carcass dissected components weights

	BCS	LW	Muscle	SCF	IMF	OMF	KKCF	STF	TF
LW	0.89**								
Muscle	0.80**	0.96**							
SCF	0.93**	0.91**	0.83**						
IMF	0.94**	0.91**	0.85**	0.97**					
OMF	0.89**	0.86**	0.82**	0.88**	0.89**				
KKCF	0.89**	0.85**	0.81**	0.91**	0.89**	0.96**			
STF	0.85**	0.85**	0.77**	0.94**	0.93**	0.83**	0.86**		
TF	0.94**	0.92**	0.86**	0.98**	0.97**	0.96**	0.96**	0.92**	
Bone	0.17^{ns}	0.20^{ns}	0.11^{ns}	0.21^{ns}	0.18^{ns}	-0.03^{ns}	-0.01^{ns}	0.22^{ns}	0.11^{ns}

** $p<0.01$, ^{ns} $p>0.05$.

TF: total fat, SCF: subcutaneous fat, IMF: intermuscular fat, OMF: omental plus mesenteric fat, KKCF: kidney knob and channel fat, STF: sternal fat.

Table 6. Multiple regression equations that improve the prediction of muscle, subcutaneous fat (SCF), intermuscular fat (IMF) and total fat (TF) weights over the respective simple regressions

Variable	Regression equation	R^2	RSD
$\log_{10}$ (muscle+1)	$-1.046+1.299 \log_{10}$ LW-0.027 BCS *	0.95	0.167
$\log_{10}$ SCF	$-2.102+1.552 \log_{10}$ BCS+1.132 $\log_{10}$ LW *	0.95	0.330
$\log_{10}$ (IMF+1)	$-0.268+1.006 \log_{10}$ (BCS+1)+0.006 LW **	0.94	0.234
$\log_{10}$ (TF+1)	$-0.901+1.123 \log_{10}$ BCS+0.863 $\log_{10}$ (LW+1) **	0.96	0.272

RSD: Residual SD; * $p<0.05$, ** $p<0.01$.

Table 7. Mean values and standard errors of subcutaneous fat (SCF), intermuscular fat (IMF), omental plus mesenteric fat (OMF) and kidney knob and channel fat (KKCF) expressed as percentages in total fat (TF)

Variable	Body condition score				SE
	1	2	3	4	
SCF/TF (%)	24.67^a	28.65^{ab}	33.24^b	33.46^b	1.73
IMF/TF (%)	44.02^b	33.96^a	28.18^a	28.25^a	1.57
OMF/TF (%)	21.33	26.35	25.71	25.07	2.28
KKCF/TF (%)	9.97	11.04	12.86	13.22	1.04

Means in the same line with different superscripts differ significantly ($p<0.01$)

Means and standard errors of age, LW, empty body weight (EBW) and dissected components, expressed in weight in half carcasses and as percentages of EBW are summarized in Table 2. No significant differences were found in age, weight of bone and percentage of muscle in EBW, whereas means of all other variables differ significantly ($p<0.01$). Teixeira et al. (1989) found similar results in the Aragonesa breed, although they recorded significant differences on bone weights between ewes with a BCS lower than 2.50 and equal or higher than 2.50.

Simple regression equations for estimating carcass dissected components expressed in weight (Table 3) and as percentages of EBW (Table 4) from BCS and LW, as well as correlation coefficients among these parameters (Table 5), showed that BCS is a better predictor of body reserves than LW, as was observed in various breeds (Russel et al., 1969; Teixeira et al., 1989; Sanson et al., 1993) but not in Churra (Frutos et al., 1997). Only the weight of muscle and the percentage of bone in the EBW were more efficiently predicted by LW than by BCS. Regression equations developed from weight of bone and percentage of muscle in EBW on BCS and LW did not provided sufficient accuracy.

Inclusion of LW as an independent variable in multiple regressions with BCS (Table 6) slightly improved the efficiency of muscle, SCF, IMF and TF weights estimation but did not afford greater precision over simple regressions with only BCS on the prediction of percentages of dissected components in EBW.

The proportions of the remaining variation accounted for (R^2 values) by BCS and LW of TF, SCF and IMF weights are slightly greater than those found by Teixeira et al. (1989), whereas for KKCF was slightly smaller. The R^2 value observed for the prediction of percentage of TF in EBW was greater than that found by Russel et al. (1969). These authors, Teixeira et al. (1989) and Sanson et al. (1993) did also not found any improvement on the efficiency of predictions with the inclusion of LW in multiple regressions with BCS.

Data showing fat partition in TF at different BCS, are set out in Table 7. Only for SCF and IMF significant differences ($p<0.01$) were found between BCS. IMF represented the largest fat depot with a BCS of 1 and 2, whereas SCF was the most important site of fat deposition with a BCS of 3 and 4. Allometric coefficients (Table 8) for each fat depot on TF suggest that the fat deposition order in ewes from this breed is: IMF, OMF, SCF and KKCF, although the *b* coefficients of the regression equations between $\log_{10}$ OMF, $\log_{10}$ SCF and $\log_{10}$ KKCF and $\log_{10}$

Table 8. Allometric coefficients (*b* values) of subcutaneous fat (SCF), kidney knob and channel fat (KKCF), omental plus mesenteric fat (OMF) and intermuscular fat (IMF) in total fat (TF)

Variable	*a+b*	$\log_{10}$ TF	R^2	SE_b	RSD
$\log_{10}$ SCF	$-0.631+1.120^b$	$\log_{10}$ TF**	0.98	0.029	0.063
$\log_{10}$ IMF	$-0.322+0.813^a$	$\log_{10}$ TF**	0.98	0.023	0.055
$\log_{10}$ OMF	$-0.688+1.078^b$	$\log_{10}$ TF**	0.94	0.052	0.114
$\log_{10}$ KKCF	$-1.061+1.127^b$	$\log_{10}$ TF**	0.96	0.044	0.095

SE_b: standard error of b; RSD: residual SD; *b* coefficients with different superscripts differ significantly. ** $p<0.01$.

Table 9. Mean values of lumbar joint (LJ) weight and muscle, subcutaneous fat (SCF), intermuscular fat (IMF) and bone of the LJ expressed in weight and as percentages in LJ

Variable	Body condition				SE
	1	2	3	4	
n	7	7	7	7	
LJ (kg)	0.261^a	0.367^b	0.446^b	0.589^c	0.024
Muscle/LJ (%)	65.00^c	56.94^{bc}	49.80^{ab}	46.37^a	2.25
SCF/LJ (%)	4.05^a	16.57^b	23.30^{bc}	30.89^c	2.59
IMF/LJ (%)	4.95	9.51	9.54	11.25	1.71
Bone/LJ (%)	25.49^b	16.81^a	17.14^{ab}	8.99^a	2.15
Muscle LJ (kg)	0.171^a	0.209^a	0.224^{ab}	0.271^b	0.015
SCF LJ (kg)	0.010^a	0.060^{ab}	0.104^b	0.187^c	0.017
IMF LJ (kg)	0.013^a	0.035^{ab}	0.042^b	0.062^b	0.007
Bone LJ (kg)	0.065	0.062	0.075	0.052	0.008

Means in the same line with different superscripts differ significantly ($p<0.01$).

Table 10. Prediction equations for estimating muscle, subcutaneous fat (SCF) and intermuscular fat (IMF) in carcass, expressed in weight and as percentages in empty body weight (EBW), from the same tissues in lumbar joint (LJ)

Variable	Regression equation	R^2	RSD
Muscle	-0.399+50.898 muscle LJ**	0.81	1.151
$\log_{10}$ SCF	1.447+0.888 $\log_{10}$ SCF LJ**	0.91	0.381
$\log_{10}$ IMF	1.614+0.816 $\log_{10}$ IMF LJ**	0.58	0.481
Bone	2.877+13.372 bone LJ**	0.39	0.616
Muscle/EBW (%)	19.55+0.121% muscle LJ*	0.18	1.558
SCF/EBW (%)	1.15+0.313% SCF LJ**	0.77	1.451
IMF/EBW (%)	4.55+0.246% IMF LJ*	0.16	1.670
Bone/EBW (%)	4.51+0.305% bone LJ**	0.76	1.177

RSD: Residual SD. * $p<0.05$; ** $p<0.01$.

TF were not different ($p>0.05$). Russel et al. (1968) and Teixeira et al. (1989) observed a different order in Aragonesa and Scottish Blackface breeds, respectively, which probably can be explained for a higher potential for meat production of these breeds in relation to that of Serra da Estrela, which is known for its milking aptitude. In fact, it is well recognized that milk breeds tend to deposit more fat in the intra abdominal depots in relation to the carcass depots than meat breeds (Truscott et al., 1983; Ferrell and Jenkins, 1984; Taylor and Murray, 1991).

Muscle is also an important depot as a protein reserve and therefore of energy, available under subnutrition conditions (Bryant and Smith, 1982; Chilliard and Robelin, 1983; Purroy et al., 1989). Mobilization and deposition of muscle may be observed in Table 2, from 7.227 kg with a BCS of 1 until 13.869 kg with a BCS of 4. BCS did not prove to be a good predictor of muscle percentage in EBW (neither did LW) (Table 4) but provided an acceptable estimate of its weight (R^2 0.67, RSD 0.071), though LW had a much better efficiency of prediction (R^2 0.93, RSD 0.032) (Table 3).

Mean values of dissected components of LJ and the relationship between these components and the same tissues in carcass are depicted in Table 9 and 10. SCF of LJ and TF of LJ (SCF plus IMF of LJ) can also be good predictors of different carcass fat depots as it is shown in Table 11. These relationships among SCF and TF of LJ and carcass fat depots are remarkable similar to those found by Delfa et al. (1989). LJ provided a reasonable estimate of both weights and percentages in EBW of all variables in carcasses. These results, in addition to those presented above on the efficiency of prediction of body composition from BCS, as Jefferies (1961), Russel et al. (1969) and Teixeira et al. (1989) as already stated in other sheep breeds, offer evidence to support LJ as a suitable anatomical region to evaluate BCS in Serra da Estrela breed.

STF was recorded in order to estimate its relationship with body reserves as an eventual alternative anatomical

Table 11. Prediction equations for estimating body condition score (BCS), omental plus mesenteric fat (OMF), kidney knob and channel fat (KKCF), subcutaneous fat (SCF), intermuscular fat (IMF) and total fat (TF) in carcasses from subcutaneous fat (SCF LJ) and subcutaneous plus intermuscular fat (SCF LJ+IMF LJ) in lumbar joint (LJ)

Variable	Regression equation	R^2	RSD
$\log_{10}$ BCS	0.869+0.414 $\log_{10}$ SCF LJ**	0.86	0.084
$\log_{10}$ BCS	-0.136+4.656 $\log_{10}$ ((SCF LJ+IMF LJ)+1) **	0.87	0.084
$\log_{10}$ OMF	1.297+0.843 $\log_{10}$ SCF LJ**	0.85	0.184
$\log_{10}$ OMF	-0.758+9.587 $\log_{10}$ ((SCF LJ+IMF LJ)+1) **	0.88	0.167
$\log_{10}$ KKCF	1.034+0.888 $\log_{10}$ SCF LJ**	0.86	0.187
$\log_{10}$ KKCF	-1.121+10.008 $\log_{10}$ ((SCF LJ+IMF LJ)+1) **	0.87	0.179
$\log_{10}$ SCF	1.447+0.888 $\log_{10}$SCF LJ**	0.91	0.145
$\log_{10}$ SCF	-0.684+9.772 $\log_{10}$ ((SCF LJ+IMF LJ)+1) **	0.88	0.167
$\log_{10}$ IMF	1.175+0.636 $\log_{10}$ SCF LJ **	0.89	0.118
$\log_{10}$ IMF	-0.359+7.069 $\log_{10}$ ((SCF LJ+IMF LJ)+1) **	0.87	0.126
$\log_{10}$ TF	1.848+0.785 $\log_{10}$ SCF LJ**	0.91	0.130
$\log_{10}$ TF	-0.051+8.774 $\log_{10}$ ((SCF LJ+IMF LJ)+1) **	0.90	0.134

RSD: Residual SD. ** $p<0.01$.

Table 12. Prediction equations for estimating total fat (TF), subcutaneous fat (SCF) and muscle in carcass, expressed in weight and as percentages in empty body weight (EBW), from sternal fat (STF)

Variable	Regression equation	R^2	RSD
TF	31.905+16.335 $\log_{10}$ STF**	0.79	1.864
SCF	10.891+5.730 $\log_{10}$ STF**	0.79	1.104
Muscle	18.199+5.637 $\log_{10}$ STF**	0.60	1.901
TF/EBW (%)	57.41+26.64 $\log_{10}$ STF**	0.83	2.230
SCF/EBW (%)	19.79+9.66 $\log_{10}$ STF**	0.85	1.292
Muscle/EBW (%)	24.26+1.45 $\log_{10}$ STF ^{ns}	0.05	1.622

RSD: Residual SD. ^{ns} not significant ($p>0.05$). ** $p<0.01$.

site (sternal region) to lumbar region to assess BCS. In goats, sternal region was found to provide greater precision on the prediction of body reserves than lumbar or caudal regions (Santucci and Maestrini, 1985; Morand-Fehr et al., 1989; Amaro and Caldeira, 1991). The proportion of remaining variation accounted for by STF on the prediction of TF and muscle weights, and on the percentage of TF in EBW (Table 12), showed that sternal region could eventually be an alternative site to evaluate BCS, although it has revealed to be a poorer predictor of body reserves than LJ. However, it will be important to remember that, under farm conditions (handling chutes), the assessment of sternal region will always be more difficult than that of lumbar region.

BCS assessed on the lumbar region demonstrate to be an excellent predictor of body reserves in Serra da Estrela ewes, providing an important tool to assess the adequacy of feeding programs and, consequently, contributing to the improvement of milk production efficiency.

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REFERENCES

Agricultural Research Council. 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureau, Slough, UK.

Amaro, R. 1990. Contribuição para o estudo da avaliação da condição corporal em cabras da raça Serrana, através da palpação de três regiões anatómicas (Contribution to the study of body condition scoring in Serrana goats by assessing three anatomical regions). MSc.Thesis, Faculdade de Medicina Veterinária, Lisboa, Portugal.

Amaro, R. P. and R. M. Caldeira. 1991. Relation entre les notes d'état corporel et la composition corporelle des chèvres de la race Serrana. Options Méditerranéennes - Séries Séminaires, 13:35-41.

Bryant, D. T. W. and R. W. Smith. 1982. The effect of lactation on protein synthesis in ovine skeletal muscle. J. Agric. Sci. (Camb.) 99:19-323.

Caldeira, R. M. and A. Vaz Portugal. 1991. Interrelationship between body condition and metabolic status in ewes. Small Rumin. Res. 6:15-24.

Chilliard, Y. and J. Robelin. 1983. Mobilization of body proteins by early lactating dairy cows measured by slaughter and D_2O dilution techniques. Colloques de l'INRA 16:195-198.

Delfa, R., A. Teixeira and F. Colomer-Rocher. 1989. A note on the use of a lumbar joint as a predictor of body fat depots in

Aragonesa ewes with different body condition scores. Anim. Prod. 49:327-329.

Evans, D. G. 1978. The interpretation and analysis of subjective body condition scores. Anim. Prod. 26:119-125.

Ferrell, C. L. and T. G. Jenkins. 1984. Relationships among various body components of mature cows. J. Anim. Sci. 58:222-233.

Frutos, P., A. R. Mantecón and F. J. Giráldez. 1997. Relationship of body condition score and live weight with body composition in mature Churra ewes. Anim. Sci. 64:447-452.

Hossamo, H. E., J. B. Owen and M. F. A. Farid. 1986. Body condition score and production in fat tailed Awassi sheep under range conditions. Research and Development in Agriculture, 2:9-104.

Huxley, J. S. 1932. Problems of relative growth. Methuen, London.

Jarrige, R. 1988. Ingestion et digestion des aliments (Feed intake and digestion). In: (Ed. R. Jarrige), Alimentation des bovins, ovins et caprins (Feeding of cattle, sheep and goat), INRA Editions, Paris, France, pp. 29-56.

Jefferies, B. C. 1961. Body condition scoring and its use in management. Tasmanian Journal of Agriculture 32:19-21.

Meat and Livestock Commission. 1983. Feeding the ewe. 2nd edn. Sheep Improvement Services, Meat and Livestock Commission, Milton Keynes, UK.

Morand-Fehr, P., A. Branca, P. Santucci and M. Napoleone. 1989. Méthodes d'estimation de l'état corporel des chèvres reproductrices (Methods of body condition estimation in goats). In: (Ed. J. C. Flamant and P. Morand-Fehr), L'évaluation des ovins et des caprins méditerranéens (Evaluation of Mediterranean sheep and goats), Proceedings of the Symposium Philoetios, Fonte Boa, Portugal, Rapport EUR 11893, Luxembourg, pp. 202-220.

Oregui, L. M., M. S. Vicente, J. Garro and M. V. Bravo. 1991. The relationship between body condition score and body weight in Latxa ewes. Options Méditerranéens - Séries Séminaires, 13:109-112.

Peart, J. N. 1970. The influence of live weight and body condition on the subsequent milk production of Blackface ewes following a period of undernourishment in early lactation. J. Agric. Sci. (Camb.) 75:459-469.

Purroy, A., F. Bocquier and A. Gibon. 1989. Méthodes d'estimation de l'état corporel chez la brebis (Methods of body condition estimation in ewes). In: (J. C. Flamant and P. Morand-Fehr), L'évaluation des ovins et des caprins méditerranéens (Evaluation of Mediterranean sheep and goats). Proceedings of the Symposium Philoetios, Fonte Boa, Portugal, Rapport EUR 11893, Luxembourg, pp. 182-201.

Russel, A. J. F., J. M. Doney and R. G. Gunn. 1969. Subjective assessment of body fat in live sheep. J. Agric. Sci. (Camb.) 72:451-454.

Russel, A. J. F., J. M. Doney and R. G. Gunn. 1971. The distribution of chemical fat in the bodies of Scottish Blackface ewes. Anim. Prod. 13:503-509.

Russel, A. J. F., R. G. Gunn and J. M. Doney. 1968. Components of weight loss in pregnant hill ewes during winter. Anim. Prod. 10:43-51.

Sanson, D. W., T. R. West, W. R. Tatman, M. L. Riley, M. B. Judkins and G. E. Moss. 1993. Relationship of body-composition of mature ewes with condition score and body-weight. J. Anim. Sci. 71:1112-1116.

Santucci, P. M. and O. Maestrini. 1985. Body composition of dairy goats in extensive systems of production: method of estimation. Annales de Zootechnie 34:473-474 (Abst.).

SAS Institute. 2003. User's Guide: Statistics, Version 9.1 ed. 2002-2003. SAS Inst., Inc., Cary, NC.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd edn. McGraw-Hill Book Company, New York.

Taylor, St. C. S. and J. I. Murray. 1991. Effect of feeding level, breed and milking potential on body tissues and organs of mature, non-lactating cows. Anim. Prod. 53:27-38.

Taylor, St. C. S., J. I. Murray and M. L. Thonney. 1989. Breed and sex-differences among equally mature sheep and goats. 4. Carcass muscle, fat and bone. Anim. Prod. 49:385-409.

Teixeira, A., R. Delfa and F. Colomer-Rocher. 1989. Relationships between fat depots and body condition score or tail fatness in the rasa Aragonesa breed. Anim. Prod. 49:275-280.

Truscott, T. G., J. D. Wood and H. J. H. MacFie. 1983. Fat deposition in Hereford and Friesian steers. 1. Body composition and partitioning of fat between depots. J. Agric. Sci. (Camb.) 100:257-270.