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## Estimation of carcase composition of goat kids from joint dissection and conformation measurements

Virgínia A. C. Santos<sup>a</sup>, António M. Silvestre<sup>b</sup>, Jorge M. T. Azevedo<sup>b</sup> and Severiano R. Silva<sup>b</sup>

<sup>a</sup>Departamento de Zootecnia, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal; <sup>b</sup>Centro de Ciência Animal e Veterinária, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

### ABSTRACT

The aim of this study was to develop equations to estimate percentages and carcase tissue weights of suckling goat kids by using cold carcase weight (CCW), carcase conformation measurements and joints tissue as independent variables. Carcases dissection data from 55 goat kids were used for regression analysis. Leg and shoulder muscle weight showed the highest positive correlations with carcase muscle weight ( $r = .98$ ). Shoulder tissue weight showed the highest correlation with carcase bone weight ( $r = .97$ ), carcase subcutaneous fat weight ( $r = .95$ ) and carcase intermuscular fat weight ( $r = .95$ ). Also, shoulder tissue percentage showed the highest correlation with carcase muscle percentage ( $r = .93$ ) and carcase subcutaneous fat percentage ( $r = .90$ ). CCW explained 95.9% of muscle weight carcase variability. The percentage of the variation explained in other tissues (bone, subcutaneous and intermuscular fat) was lower, but not negligible (89.6%, 60.7% and 48.7%, respectively). Chest circumference and carcase compactness presented the highest correlation with weight of carcase tissues, especially with muscle weight ( $r = .93$ ), bone weight ( $r = .93$  and  $.89$ , respectively), subcutaneous fat ( $r = .71$  and  $.79$ ) and intermuscular fat weight ( $r = .68$  and  $.67$ ). The results of this study support the conclusion that the shoulder tissue composition allows accurate estimation of the carcase composition. Also, CCW, chest circumference and carcase compactness measurements were good predictors of the weight of carcase tissues in goat kids, with the advantage to be non-destructive and easy to obtain.

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### Introduction

The knowledge of carcase composition is essential in animal science and can be used for several purposes. According to Stanford et al. (1998) carcase composition assessment serves three objectives: assigns carcase value; allows sorting of carcasses for further processing or fresh meat merchandising; and transfers information back to the production sector. Adequate fat levels and a higher proportion of lean to bone are important factors for determining carcase quality. The total physical separation of the carcase into lean, fat and bone is the most accurate method for estimating carcase composition (Argüello et al. 2001; Maeno et al. 2014). However, this technique is very expensive because it is time-consuming, devalues the carcase and requires specialised labour (Santos-Silva & Simões 1999; Maeno et al. 2014). To overcome these difficulties, and having the carcase as focus, efforts have

been made to develop rapid, simple, objective and inexpensive methods. Some of these methods are based on carcase measurements (Díaz et al. 2004; Znamirowska 2005; Lambe et al. 2009), on tissue measurements (Znamirowska 2005; Hopkins et al. 2008), in tissue joints composition (Tahir et al. 1994; Argüello et al. 2001; Oliván et al. 2001; Dhanda et al. 2003; Maeno et al. 2014; McEvers et al. 2015) or in shoulder composition combined with total dissection (Cameron 1992; Lewis et al. 1996; Van Heelsum et al. 2003; Conington et al. 2010). According to Kempster (1981) the dissection of different joints allows the best predictors of carcase tissue composition. Studies performed in goats showed that the composition of the whole carcase could be predicted from the composition of primal cuts (Tahir et al. 1994; Argüello et al. 2001; Dhanda et al. 2003). Developing prediction equations of carcase composition of older/heavier

**CONTACT** Prof Virgínia A. C. Santos  vsantos@utad.pt  Departamento de Zootecnia, Escola de Ciências Agrárias e Veterinárias, Universidade de Trás-os-Montes e Alto Douro, Vila Real 5000-801, Portugal

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animals have already been described (e.g. Kempster et al. 1986). However little is known about prediction equations of carcass composition of young animals and according to Díaz et al. (2004) if estimation equations of heavier lambs are applied in suckling lambs the carcass composition is misestimated since there are important differences between them in carcass composition. This problem is expected for goat suckling kids. The meat of suckling goat kids is highly valued and with great demand in Portugal, as in other Mediterranean countries. Most of this meat is a qualified product recognised with European meat quality labels (Commission Regulation EU No. 1151/2012), such as Protected Geographical Indication (PGI) or Protected Designation of Origin (PDO). To better meet consumer demand, carcasses must be evaluated using quality attributes such as tenderness, cut size, fat cover, marbling, meat and fat colour; and composition attributes such as saleable meat yield, or proportions of fat, lean and bone (Stanford et al. 1998). The objective of this study was to investigate the accuracy of eight joint tissue weights and percentages, conformation measurements and carcass weight as estimators of carcass tissue composition of goat kids.

## Materials and methods

### Animals

The experimental group consisted of 55 suckling goat kids (27 males and 28 females) from seven herds of Portuguese native breeds produced according to 'Cabrito de Barroso-PGI' specifications (Santos et al. 2007). 'Cabrito de Barroso-PGI' is a European meat quality label (Commission Regulation EC No. 1107/96) that has some specificity attributed to a particular region and a traditional production method. Succinctly, according to PGI specifications, the 'Cabrito de Barroso-PGI' carcasses must have a weight between 4 and 6 kg, from kids up to 3 months of age. The kids are raised on pasture with their dams in the north of Portugal (Barroso region) and belong to the local Serrana or Bravia goat breeds or their crossbreeds, mainly used, for meat production. The Serrana and Bravia breeds have similar body size with an adult body weight of 25–40 kg and 35–50 kg for females and males, respectively (SPOC 2016). Goat kids were weekly weighed and when reached a range of live body weight (BW) between 8 and 11 kg they were separated from their dams and transported to the slaughterhouse. Slaughter body weight (SBW) was recorded after 14 h of fasting with free access to water (Table 1). Kids were slaughtered using standard commercial procedures.

**Table 1.** Mean, standard deviation (SD) and coefficient of variation (CV) of SBW, CCW, conformation measurements, joints percentage and carcass composition in tissues (weight and percentage) of half carcass of goat kids ( $n = 55$ ).

Item	Mean	SD	CV, %
SBW, kg	10.0	1.95	19.4
CCW, kg	4.8	1.10	22.9
Conformation measurements			
Chest circumference, cm	48.4	3.51	7.3
Anterior buttock circumference, cm	35.6	3.46	9.7
Posterior buttock circumference, cm	39.3	3.12	7.9
Carcass internal length, cm	44.2	3.60	8.1
Leg length, L, cm	30.0	2.17	7.2
Carcass compactness index, CCW/L, $\text{kg}\cdot\text{m}^{-1}$	10.8	1.81	16.7
Joints			
Leg, %	25.1	1.06	4.2
Chump, %	8.3	0.64	7.6
Loin, %	10.5	0.76	7.2
Ribs, %	6.6	0.48	7.2
Anterior rib, %	5.7	0.45	8.0
Shoulder, %	22.6	0.95	4.2
Breast, %	11.6	1.13	9.8
Neck, %	9.7	0.92	9.5
Carcass composition in tissues weight			
Muscle, g	1437.0	324.0	22.6
Subcutaneous fat, g	92.7	42.4	45.7
Intermuscular fat, g	197.2	82.5	41.8
Dissected fat, g	289.9	120.7	41.6
Bone, g	463.6	97.2	21.0
Carcass composition in tissues percentage			
Muscle, %	64.8	2.79	4.3
Subcutaneous fat, %	4.1	1.15	28.3
Intermuscular fat, %	8.7	2.54	29.0
Dissected fat, %	12.8	3.40	26.6
Bone, %	21.0	1.41	6.7

### Carcass measurements, jointing and dissection

Carcass dressing and measurements were performed according to the method of Fisher and de Boer (1994). After slaughtering and evisceration carcasses were chilled for 24 h at  $+4^\circ\text{C}$ , and after that, cold carcass weight (CCW) was recorded. From all carcasses the following measurements were recorded: internal leg length (from the symphysis pubis to the tarsal-metatarsal joint), internal carcass length (L; length from anterior edge of the symphysis pubis to the anterior edge of the first rib), anterior buttock circumference (measured at the proximal edges of the two trochanters), posterior buttock circumference (measured at the proximal edges of the two patellae) and chest circumference. Also, it was determined the carcass compactness, used as a conformation indicator, as the ratio between CCW and internal carcass length measure ( $\text{CCW}/L, \text{kg}\cdot\text{m}^{-1}$ ). After the removal of the kidney knob and channel fat, carcasses were split down the dorsal midline and the left side was divided into eight commercial cuts as described by Santos et al. (2008). After, each cut was weighed, placed in a sealed plastic and frozen for later dissection into muscle, bone, fat (subcutaneous and intermuscular fat depots were weighed separately) and the remainder (major blood, vessels,

**Table 2.** Correlation coefficients (*r*) between predictors and carcass composition (*n* = 55).

Predictors	Tissue weight, g				Tissue percentage, %			
	M	B	SF	IF	M	B	SF	IF
Cold carcass weight, g	0.98***	0.95***	0.78***	0.70***	0.12 <sup>ns</sup>	0.40**	0.40**	0.19 <sup>ns</sup>
Chest circumference, cm	0.93***	0.93***	0.71***	0.68***	0.16 <sup>ns</sup>	0.34*	0.34*	0.21 <sup>ns</sup>
Anterior buttock circumference, cm	0.80***	0.77***	0.64***	0.52***	0.07 <sup>ns</sup>	0.32*	0.36**	0.11 <sup>ns</sup>
Posterior buttock circumference, cm	0.84***	0.82***	0.62***	0.54***	0.07 <sup>ns</sup>	0.30*	0.30*	0.12 <sup>ns</sup>
Carcass internal length, cm	0.83***	0.84***	0.53***	0.56***	0.05 <sup>ns</sup>	0.21 <sup>ns</sup>	0.13 <sup>ns</sup>	0.12 <sup>ns</sup>
Long leg length, cm	0.92***	0.93***	0.68***	0.65***	0.15 <sup>ns</sup>	0.28*	0.31*	0.19 <sup>ns</sup>
Carcass compactness, kg/m <sup>2</sup>	0.93***	0.89***	0.79***	0.67***	0.13 <sup>ns</sup>	0.43**	0.47***	0.20 <sup>ns</sup>

M: muscle; B: bone; SF: subcutaneous fat; IF: intermuscular fat.

<sup>ns</sup>Not significant correlation ( $p > .05$ ).

\*Significant correlation ( $p < .05$ ).

\*\*Very significant correlation ( $p < .01$ ).

\*\*\*Highly significant correlation ( $p < .001$ ).

ligaments, tendons, and thick connective tissue sheets associated with some muscles). The tissues were joined together and analysed as carcass composition. The dissection work was done by a trained technician in a dissection room under controlled environment with a temperature maintained below 15 °C.

### Statistical analysis

Data were subjected to correlation and regression analysis performed with GLM procedure (SAS Inst. Inc., Cary, NC). Correlations were determined to study the relationships between carcass tissue composition (weight and percentage) and carcass weight, carcass conformation measurements and joint tissue weights and percentages. The regression analyses were used to estimate carcass muscle, bone, subcutaneous fat and intermuscular fat weights and percentages. The simple regression equations were evaluated with the determination coefficient ( $r^2$ ) and the residual standard deviation (RSD). In a preliminary analysis, the effect of sex and the heterogeneity of slopes were examined by covariance analysis. At this BW, it was observed that the effect of sex and the heterogeneity of slopes were not significant, and the accuracy or precision of the model was not improved if gender was included.

### Results and discussion

Descriptive statistics of SBW, CCW, carcass conformation measurements, joints percentage and carcass composition of kids are presented in Table 1. The average CCW is in accordance to PGI specifications of the 'Cabrito de Barroso-PGI' and is also a representative sample of the suckling kids slaughtered in the Portuguese carcass market. At this range of SBW, the carcass conformation measurements, with carcass compactness index exception, have low variability

(CV <10%). For carcass composition, variability was higher for fat carcass tissues than for muscle and bone tissues. The percentage of joints obtained in this study is similar to that reported for other Mediterranean goat breeds slaughtered at similar weights (Dhanda et al. 2003; Marichal et al. 2003; Peña et al. 2007; Vacca et al. 2014). In general, the carcass tissue percentages of 'Cabrito de Barroso' kids are similar to those found on goat kids of Capretto group (Dhanda et al. 2003). Comparisons with other goat breeds with comparable feeding treatment and slaughtered at equivalent weights show that dissected fat was similar to the one reported for Florida breed (Peña et al. 2007) and higher than those for Sarda breed (Vacca et al. 2014).

### Correlation analysis

The correlation coefficients between carcass composition (weight and percentage) with CCW or carcass conformation measurements are listed in Table 2. In general, correlations between carcass tissue weights and CCW or conformation measurements were high, whereas predictors' correlations with carcass tissue percentages were low ( $r < .50$ ) or even not significant. CCW is straightforward and rapid to obtain and displayed a high association with carcass tissue weights ( $r$  ranging .70–.98) (Table 2). Several authors, with different animal species or heavier animals, have also reported high correlation coefficients between carcass and tissue weights (Díaz et al. 2004; Maeno et al. 2014). Díaz et al. (2004) showed that CCW displayed the highest correlation (.961) with the muscle weight of suckling lambs of the Manchego sheep breed. In that study, CCW explained 92.3% of the variation in muscle content of the carcass. The highly significant correlation between CCW and muscle weight was expected, because the carcass weight is directly

**Table 3.** Correlation coefficients between carcass tissues (weight and percentage) and the corresponding tissue in the carcass joints ( $n = 55$ ).

Carcass tissues	Carcass joints							
	Leg	Chump	Loin	Ribs	Anterior rib	Shoulder	Breast	Neck
Weight, g								
Muscle	0.98***	0.97***	0.96***	0.96***	0.93***	0.98***	0.96***	0.94***
Bone	0.96***	0.85***	0.80***	0.78***	0.85***	0.97***	0.86***	0.76***
Subcutaneous fat	0.87***	0.86***	0.94***	0.72***		0.95***	0.91***	0.35*
Intermuscular fat	0.94***	0.78***	0.93***	0.91***	0.93***	0.95***	0.94***	0.89***
Percentage, %								
Muscle	0.80***	0.76***	0.81***	0.68***	0.81***	0.93***	0.89***	0.63***
Bone	0.86***	0.58***	0.59***	0.15 <sup>ns</sup>	0.62***	0.83***	0.69***	0.61***
Subcutaneous fat	0.76***	0.81***	0.88***	0.48***	0.90***	0.90***	0.78***	0.22 <sup>ns</sup>
Intermuscular fat	0.90***	0.67***	0.92***	0.84***	0.94***	0.93***	0.90***	0.87***

<sup>ns</sup>Not significant correlation ( $p > .05$ ).\*Significant correlation ( $p < .05$ ).\*\*\*Highly significant correlation ( $p < .001$ ).

related to the total weight of carcass components as reported by Maeno et al. (2014).

Conformation measurements displayed greater correlations with tissue weights than with tissue percentages, in fact, all correlations between conformation measurements and muscle and intermuscular fat percentages were not significant (Table 2). Also Díaz et al. (2004) found, in suckling lambs, that the correlations between conformation and tissue percentages were in most cases not significant. In that study, chest width presented the highest correlation coefficients with the percentage of carcass tissues, and especially with fat carcass percentage ( $r = .491$ ;  $p < .001$ ). In our study, chest circumference and carcass compactness were the most highly correlated measurements with the weight of carcass tissues (Table 2). In suckling lambs, carcass internal length and buttock perimeter showed the highest correlations with the weight of carcass tissues (Díaz et al. 2004).

Significant correlations were observed between the weights and percentages of muscle, fat and bone in most of the joints and that in the carcass side (Table 3). Tahir et al. (1994) and Dhanda et al. (2003) also reported that the composition of the whole carcass in goats could be predicted from the composition of primal cuts. In our study, leg and shoulder muscle weight showed the highest positive correlations with carcass muscle weight, additionally, shoulder tissue weight showed the highest correlations with carcass bone, subcutaneous fat and intermuscular fat weight. Also, shoulder tissue percentage showed the highest correlation with carcass muscle percentage ( $r = .93$ ) and carcass subcutaneous fat percentage ( $r = .90$ ). Tahir et al. (1994) found that the most convenient joint for prediction of muscle, fat and bone content of the Iraqui indigenous black goat carcasses was the breast. El Karim et al. (1988) established relationships

between percentage tissue in the side and percentage tissue in the different joints of two types of Sudan Desert lambs. Results of joints dissection showed that the percentage of lean in the middle neck and shoulder, leg and best end, in this order, were strongly associated with the lean percentage ( $p < .001$ ). The bone percentage on the middle neck and shoulder, leg and loin was positively associated with bone percentage. Fat in the leg and best end neck gave a highly significant correlation ( $p < .001$ ) with fat percentage. Similarly, Kempster et al. (1986) evaluated the proportions of tissues in joints as predictors of carcass composition of crossbred lambs of different breeds and crosses. Also, the precision of the sample joints was examined in relation to their dissection cost. These authors reported that the best end neck and shoulder joints offered a high precision level with reduced dissection cost.

### **Estimation of carcass composition from CCW, conformation measurements and dissection by simple regressions**

The three best prediction equations for muscle, bone, subcutaneous fat and intermuscular fat (weights and percentages) generated by simple regression are presented in Table 4. The equation that best predict the carcass composition using conformation measurement is also presented in Table 4. Prediction equations for the tissue weights were more accurate (higher  $r^2$ ) than prediction equations for the tissue percentages. Similar results were obtained by Díaz et al. (2004) using objective and subjective carcass measurements for prediction the carcass composition (weight or percentage) of suckling lambs. In this study, CCW explained 95.9% of the carcass muscle weight variability. The variability percentage explained by CCW in other

**Table 4.** Equations for estimation the carcass tissue weights and percentages from carcass weight, carcass measurements and joints tissues dissection.

Dependent variable (y)	Independent variable (x)	$r^2$	RSD	$p$	Slope	Intercept
Carcass M, g	Leg M, g	.965	61.43	***	3.77	-17.99
	Shoulder M, g	.963	63.00	***	4.43	-17.57
	CCW, g	.959	66.02	***	0.58	51.28
	Chest circumference, cm	.874	116.29	***	86.19	-2736.3
Carcass B, g	Shoulder B, g	.950	22.05	***	4.12	-0.93
	Leg B, g	.922	27.42	***	3.63	-6.93
	CCW, g	.896	31.71	***	0.17	61.91
	Chest circumference, cm	.864	36.21	***	25.715	-781.46
Carcass SF, g	Shoulder SF, g	.906	13.10	***	3.67	7.34
	Loin SF, g	.875	15.11	***	4.95	30.45
	Breast SF, g	.825	17.88	***	3.99	12.79
	Carcass compactness, kg·m <sup>-1</sup>	.630	26.04	***	18.62	-108.41
Carcass IF, g	Shoulder IF, g	.904	25.80	***	4.99	13.66
	Breast IF, g	.889	27.68	***	4.07	13.03
	Leg IF, g	.875	29.47	***	7.49	-2.79
	Chest circumference, cm	.460	61.16	***	15.92	-573.70
Carcass M, %	Shoulder M, %	.865	1.03	***	1.03	-2.69
	Breast M, %	.799	1.26	***	0.54	35.90
	Loin M, %	.661	1.64	***	0.58	22.69
Carcass B, %	Leg B, %	.745	0.72	***	0.81	2.24
	Shoulder B, %	.683	0.80	***	0.81	2.81
	Breast B, %	.481	1.02	***	0.34	13.97
Carcass SF, %	Shoulder SF, %	.815	0.50	***	0.72	0.82
	Loin SF, %	.771	0.56	***	0.45	1.73
	Chump SF, %	.658	0.68	***	0.35	1.62
Carcass IF, %	Anterior rib IF, %	.882	0.88	***	0.49	2.87
	Shoulder IF, %	.858	0.97	***	1.12	0.77
	Loin IF, %	.838	1.03	***	0.84	2.59

$r^2$ : Coefficient of determination; M: muscle; B: bone; SF: subcutaneous fat; IF: intermuscular fat; RSD: residual standard deviation.

\*\*\*Highly significant correlation ( $p < .001$ ).

tissues (bone, subcutaneous and intermuscular fat) was lower but not negligible (89.6%, 60.7% and 48.7%, respectively). These results can be justified by the young age of the animals and the different relative growth rates of the carcass tissues, especially fat percentage of the carcass, which increases significantly with age (allometric coefficient 1.234, Peña et al. 2007). In lambs of Greek dairy sheep breeds, Zygoiannis et al. (1990) have found linear prediction equations with high coefficients of determination ( $r^2 > .95$ ) using carcass weight as the independent variable for estimation of the muscle, bone and fat tissues. Also, Díaz et al. (2004), using a stepwise procedure in the prediction of muscle and bone, the CCW appeared in the first step and in the prediction of carcass fat the CCW was included in the second step by the carcass compactness index.

In general, the best estimates of carcass tissue weights and percentages were obtained using shoulder and leg dissection (Table 4). However, as mentioned above, the  $r^2$  values were lower for the

estimation of tissue percentages. Shoulder joint dissection was used for estimation of carcass composition with satisfactory results in lambs (Kempster et al. 1986; El Karim et al. 1988). In those studies, the shoulder was chosen because it can be easily dissected and was not considered of a high commercial value cut. In contrast, the estimation of the carcass composition of goat kids by use of joint dissection showed that the shoulder dissection has a medium  $r^2$  (.41-.73) but when regressions were calculated using shoulder dissection and also carcass weight the estimates were improved (0.70-0.81) (Argüello et al. 2001).

Studies conducted with lambs showed that estimation equations based on lambs raised under specific conditions, such as type of production, gender, age or even breed should not be applied outside of those circumstances (Kempster 1981; Safari et al. 2001). Therefore, and similarly with kids, further work should be done in order to obtain estimation equations of carcass composition that could be applicable to a wide range of situations with economical interest.

## Conclusions

The results of this study support the conclusion that the shoulder tissue composition allows accurate estimation of carcass muscle, bone, subcutaneous fat and intermuscular fat weights and percentages. Also, shoulder joint has the advantage to be easy to dissect. CCW alone was a good predictor of the weight of the carcass tissues, especially for muscle, due to its accuracy (high  $r^2$ ) and easiness to attain. The conformation measurements tested, especially chest circumference and carcass compactness, presented high correlations with carcass tissues weight. These measurements are easy to measure, are non-destructive and should be considered as good predictors of carcass tissue weights.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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