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Original

Prediction of the carcass tissue composition of "Blackbelly" lambs using *in vivo* and *postmortem* measurements

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ABSTRACT

Objective. Predict the tissue carcass composition of "Blackbelly" lambs using *in vivo* and *postmortem* measurements. **Materials and methods.** Twenty lambs with an average age and weight of seven months and 29.07±2.88 kg, respectively, were used. Before slaughter, the subcutaneous fat thickness, depth, width and *Longissimus dorsi* muscle area were measured with ultrasonography. After slaughter, the cold carcass and tissues: muscle, fat and bone weight, were recorded. In the carcass, the thoracic depth, length, perimeter, length and width of the leg, as well as the compactness index, were also measured and recorded. Correlation analysis and regression models were used to predict tissue carcass composition. **Results.** The carcass tissues were correlated with *L. dorsi* muscle depth ($p \leq 0.05$; r-values ranged from 0.67 to 0.80) and carcass compactness index ($p \leq 0.05$; r ranged from 0.54 to 0.75). The r^2 for the prediction equations of the carcass tissue composition ranged from 0.71 to 0.78 for fat ($p \leq 0.001$). **Conclusions.** The use of *in vivo* and *postmortem* measurements allowed the prediction of tissue carcass composition of lambs, with moderate to high accuracy (r^2 >0.71≤ and ≤0.78).

Keywords: Barbados Blackbelly; biometry; longissimus dorsi; body measurements; bone-muscle ratio (*Source: CAB*).

RESUMEN

Objetivo. Predecir la composición tisular de canales de corderos "Blackbelly" usando mediciones *in vivo* y *postmortem*. **Materiales y métodos.** Se utilizaron 20 corderos con una edad de siete meses y peso de 29.07±2.88 kg en promedio. Antes del sacrificio, se midió con ultrasonografía la grasa subcutánea, la profundidad, la amplitud y el área del músculo *Longissimus dorsi*. Posterior al

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sacrificio, se registró el peso de la canal y de los tejidos: músculo, grasa y hueso. En la canal, también se midió y registró la profundidad torácica, el largo, el perímetro, el largo y ancho de la pierna, así como el índice de compacidad. Para predecir la composición tisular de las canales se usó análisis de correlación y modelos de regresión. **Resultados.** Los tejidos de la canal se correlacionaron con la profundidad del músculo *L. dorsi* ($p \leq 0.05$; r entre 0.67 y 0.80) y con el índice de compacidad de la canal ($p \leq 0.05$; r varió de 0.54 a 0.75). Las ecuaciones de predicción de la composición tisular de la canal tuvieron una r^2 que osciló entre 0.71 a 0.78 para el tejido graso ($p \leq 0.001$). **Conclusiones.** El uso de mediciones *in vivo* y *postmortem* permitieron predecir la composición tisular de canales de corderos con una precisión de moderada a alta ($r^2 > 0.71 \leq$ y ≤ 0.78).

Palabras clave: Barbados Blackbelly; biometría; *longissimus dorsi*; medidas corporales; proporción hueso músculo (*Fuente: CAB*).

INTRODUCTION

Carcass tissue composition can be determined by various techniques, among which are those that are complex, expensive, and limited to laboratory conditions and those that are simple and can be done through *in vivo* and *postmortem* measurements of animals (1,2,3,4).

Ultrasonography, defined as a non-invasive procedure to observe the tissues and organs inside the body, has been used to predict the carcass composition (5) and the muscle and body fat of animals under *in vivo* conditions (6). However, few studies have used ultrasonography as an alternative technique to predict the carcass composition of hair sheep (5,6). Additionally, it has been reported that it is possible to predict carcass tissue composition using *postmortem* measurements indicating the degree or level of fat that the animals store in their body (fat depots, subcutaneous fat, abdominal fat), as well as their conformation (7).

The use of *in vivo* or *postmortem* measurements offers an advantage over other techniques (*e.g.* dissection of cuts or the whole carcass) since they are less complex and easier to perform and do not cause loss of carcass tissue (8). In addition, with the use of these measurements, whether *in vivo* or *postmortem,* or a combination of both, it is possible to increase the accuracy of the predictions (9). In this case, the carcass tissue composition prediction is made through mathematical equations, which have been previously used in lambs (8).

In sheep production systems in tropical regions, hair breeds such as "Pelibuey" and "Blackbelly" (6,10) predominate, but little is known about their carcass characteristics and composition, as well as the factors that could affect them (11,12). The "Blackbelly" breed is considered an alternative to increasing meat production (11). Due to this fact, it is important to study its carcass characteristics and composition; in addition, it is important to promote its genetic and cultural value as well as its relevance as a potential source of income and employment for low-income farmers, and the food security that it implies (11,12,13). Therefore, the objective of the present study is to predict the carcass tissue composition of "Blackbelly" lambs using *in vivo* and *postmortem* measurements.

MATERIALS AND METHODS

Location. The study was carried out at the Centro de Integración Ovina del Sureste (CIOS), located at R/a Alvarado Santa Irene 2da. Secc., in the municipality of Centro, Tabasco, Mexico. The region is located in the humid tropics of Mexico, with average annual temperatures of 26°C.

Experimental animals. Twenty 7-month-old lambs with an average weight of 29.07 ± 2.88 kg were used, purchased from a commercial farm in the State of Tabasco dedicated to the production of breeding stock of the "Blackbelly" breed. Lambs were housed in raised slatted floor cages with a group feeding system and fed with a total mixed diet (80:20 concentrate to forage ratio) containing ground corn, soybean meal, star grass hay, and a premix of vitamins and minerals. The diet had a crude protein level of 15% and 12 MJ of metabolisable energy.

***In vivo* measurements.** The weight of the animals was recorded after fasting for 24 h (SBW, kg). Subcutaneous fat (SFT, cm) and the *longissimus dorsi* muscle area (LDMA, cm^2) were measured using Mindray DP Vet 50 B-mode ultrasonography equipment with a 7.5

MHz linear probe (Mindray Ltd. and National Ultrasound Inc.; Wuxi, Jiangsu, China) displaced between the 12th and 13th thoracic vertebrae. Likewise, the maximum amplitude (ALDM, cm) and depth (DLDM, cm) of the *longissimus* muscle were measured to calculate the LDMA (cm^2), using the formula described by Morales-Martínez et al. (7):

$$LDMA\ cm^2 = ([ALDM / 2 \times DLDM / 2] \times \pi)$$

***Postmortem* measurements.** The animals were slaughtered after fasting for 24 h, following the Official Mexican Standards (NOM-033-SAG/ZOO-2014) that refer to the methods for the slaughtering of domestic and wild animals. The hot carcass (HCW) was weighed and cooled for 24 h at 1°C, to weigh the cold carcass (CCW, kg). The carcass was divided along the dorsal midline and in the left half carcass (cold), thoracic depth (TD, maximum length between the sternum and vertebral column at the level of the 6th rib), carcass length (CL, maximum length between the anterior end of the ischio-pubic joint and the anterior end of the 1st rib). Also, the perimeter of the leg (PL, maximum length around the leg), the length (LL), and width (LW) of the leg were measured on the hindquarters. Additionally, the carcass compactness index (CCI) was calculated using the formula described by Ruiz de Huidobro et al. (14) and Carrasco et al. (15):

$$CCI = CCW/CL$$

Analysis of data. A descriptive statistical analysis was performed using PROC MEANS (16). To evaluate the relationship between the carcass tissue composition (muscle, fat and bone) and *in vivo* and *postmortem* measurements, Pearson's correlation analysis and regression models were used using PROC CORR and PROC REG of the SAS statistical program, respectively (16). The STEPWISE and Mallow's Cp options were used in the SELECTION statement. The criteria for choosing the models were based on the highest coefficient of determination (r^2), the lowest mean square error (MSE) and the lowest root of the MSE (RMSE).

RESULTS

The mean values, standard deviation, and minimum and maximum of the variables of *in vivo* and *postmortem* measurements in "Blackbelly" lambs are shown in Table 1. Based on the descriptive statistical analysis, it was observed that the SFT was 0.05 cm on average, with a minimum of 0.02 and a maximum of 0.06 cm. In the ALDM and the DLDM, a difference was observed from 2.01 to 3.76 cm and from 1.18 to 2.29 cm, respectively. The LDMA was 4.11 cm^2 on average, with a minimum of 2.63 and a maximum of 5.61 cm^2. The CCW varied from 9.90 to 17.57 kg. Among the measurements of the carcass, it is important to highlight that the TD presented a range from 21.80 to 28.90 cm, while in the CL it was from 47.20 to 58.00 cm. Variations in PL, LL, and LW were also observed (Table 1). Regarding the CCI, an average of 0.24 kg/cm and a range of 0.19 to 0.31 kg/cm were observed. Finally, the weight of carcass tissues ranged from 6.79 to 10.92 kg for muscle, from 0.77 to 2.08 kg for fat, and from 2.19 to 3.98 kg for bone.

Table 1. Mean values, standard deviation (SD), and minimum and maximum of the variables of *in vivo* and *postmortem* measurements in "Blackbelly" lambs.

In vivo	**Variable**				
	Desc	**Mean**	**SD**	**Min**	**Max**
Subcutaneous fat thickness (cm)	SFT	0.05	0.01	0.02	0.06
Amplitude of *l. dorsi* muscle (cm)	ALDM	3.06	0.51	2.01	3.76
Depth of *l. dorsi* muscle (cm)	DLDM	1.71	0.25	1.18	2.29
L. dorsi muscle area (cm^2)	LDMA	4.11	0.90	2.63	5.61
Postmortem					
Cold carcass weight (kg)	CCW	13.30	1.94	9.90	17.57
Thoracic depth (cm)	TD	25.88	1.68	21.80	28.90
Carcass length (cm)	CL	53.17	2.83	47.20	58.00
Leg perimeter (cm)	LP	50.11	5.80	39.00	58.80
Leg length (cm)	LL	23.67	2.59	21.30	28.00
Leg width (cm)	LW	7.21	0.69	5.80	8.30
Carcass compactness index (kg/cm)	CCI	0.24	0.03	0.19	0.31
Total carcass muscle (kg)	TCM	8.73	1.24	6.79	10.92
Total carcass fat (kg)	TCF	1.31	0.38	0.77	2.08
Total carcass bone (kg)	TCB	2.89	0.39	2.19	3.98

Desc: Description; Min: Minimum; Max: Maximum.

The correlation coefficients corresponding to the variables of *in vivo* and *postmortem* measurements in "Blackbelly" lambs are shown in Table 2. A significant correlation (p≤0.05) was observed between on one hand CCW and DLDM (0.82), and, on the other, CCI (0.87), TD (0.66), and the carcass tissues (Table 2). The LDMA was also correlated (p≤0.05) with the ALDM (0.64), CCI (0.71), TD (0.50), and LP (0.48) as well as the TCM (0.67) and TCB (0.80) carcass tissues (except TCF; Table 2). The ALDM was only positively related (p≤0.05) to LDMA (0.69). The LDMA was only related to LP and TCB (p≤0.05). On the other hand, the CCI had a significant correlation (p≤0.05) with the TD and carcass tissues, with values of 0.75, 0.73, and 0.54 for TCM, TCF, and TCB, respectively. The TD was only related to the TCB (0.50), while the CL was related to the LP (0.51) and the TCB (0.67). The LW had a positive relationship (p≤0.05) only with the LP (0.58). Finally, it was observed that the TCM was correlated (p≤0.05) with the TCF (0.73) and the TCB (0.62).

The equations for predicting the carcass composition (muscle, fat, and bone) of "Blackbelly" lambs from *in vivo* and *postmortem* measurements are shown in Table 3. All equations are significant (p≤0.001). The r^2 ranges from 0.71 for the TCM (RMSE= 0.69) to 0.78 for the TCB (RMSE= 0.17) and includes as predictors the CCI, LP, CL, and DLDM.

Tabla 2. Correlation coefficients corresponding to the variables measured *in vivo* and *postmortem* in "Blackbelly" lambs.

	CCW	SFT	DLDM	ALDM	LDMA	CCI	TD	CL	LW	LP	LL	TCM	TCF	TCB
CCW	1	0.14	0.82*	-0.24	0.38	0.87*	0.66*	0.35	0.25	0.18	-0.05	0.80*	0,64*	0.80*
SFT		1	-0.05	0.04	-0.04	-0.03	0.16	0.22	-0.12	0.06	-0.01	0.13	-0.15	0.14
DLDM			1	-0.09	0.64*	0.71*	0.50*	0.42	0.32	0.48*	-0.03	0.67*	0.39	0.80*
ALDM				1	0.69*	-0.27	-0.46*	0.13	0.05	0.08	-0.05	-0.20	-0.12	0.10
LDMA					1	0.28	0.28	0.41	0.28	0.45*	-0.07	0.31	0.17	0.50*
CCI						1	0.62*	-0.10	0.24	0.01	-0.12	0.75*	0.73*	0.54*
TD							1	0.11	0.12	0.17	-0.16	0.37	0.36	0.50*
CL								1	0.13	0.51*	0.18	0.26	0.03	0.67*
LW									1	0.58*	-0.49*	0.40	0.31	0.20
LP										1	-0.20	0.24	0.11	0.39
LL											1	-0.10	-0.12	0.14
TCM												1	0.73*	0.62*
TCF													1	0.37
TCB														1

*p≤0.05, CCW = Cold carcass weight (kg), SFT = Subcutaneous fat thickness (cm), DLDM = Depth of *l. dorsi* muscle (cm), ALDM = Amplitude of *l. dorsi* muscle (cm), LDMA = *l. dorsi* muscle area (cm^2), CCI = Carcass compactness index (kg/cm), TD = Thoracic depth (cm), CL = Carcass length (cm), LW = Leg width (cm), LP = Leg perimeter (cm), LL = Leg length (cm), TCM = Total carcass muscle (kg), TCF = Total carcass fat (kg), TCB = Total carcass bone (kg).

Table 3. Equations to predict the carcass tissue composition (muscle, fat and bone)

No.	Equation	*r*²	MSE	RMSE	p-Value
1	TCM (kg)= 0.83 (±1.25*) + 31.73 (±5.01***) × CCI	0.71	0.48	0.69	<.0001
2	TCF (kg)= 0.002 (±0.51*) + 10.23 (±1.62***) × CCI -0.02 (±0.01*)× LP	0.72	0.04	0.20	0.003
3	TCB (kg)= -1.74 (±0.86*)+ 0.95 (±0.19***)× DLDM+0.05 (±0.01*)× CL	0.78	0.03	0.17	<.0001

*p≤0-05; ** p≤0-001, TCM = Total carcass muscle (kg), TCF = Total carcass fat (kg), TCB = Total carcass bone (kg), ICC = Carcass compactness index (kg/cm), LP = Leg perimeter (cm), CL = Carcass length (cm), DLDM = Depth of *l. dorsi* muscle (cm), MSE = Mean square of error, RMSE = Root mean square of error.

DISCUSSION

Due to how laborious and costly it is to find out the carcass tissue composition (since its complete dissection is required), alternative techniques have been evaluated for its determination. Some studies aimed at predicting the carcass tissue composition of animals destined for human consumption have promoted the use of commercial cuts of the carcass, such as neck, shoulders, ribs and loin, as well as other measurements of the carcass, to evaluate them as predictors of the carcass tissue composition of small ruminants (17,18). Likewise, carcass tissue composition is significantly correlated with animal growth and body weight (19,20). Other authors have reported that carcass tissue composition can be predicted by measurements taken *in vivo* and on the carcass, such as the degree of fatness and carcass conformation (7,8). The use of these measures offers an advantage over commercial cut dissection, as they are quicker and easier to obtain and do not involve any loss of carcass tissue (8). However, few reports in the literature evaluate whether it is possible to increase the accuracy of predictions using different measurements taken on the live animal or the carcass, or combinations of both measurements.

The present work is one of the first to report the use of *in vivo* (taken by ultrasonography) and *postmortem* (in the carcass) measurements to predict the carcass tissue composition of "Blackbelly" lambs. In other studies it has been shown that it is possible to predict the TCM (r^2 from 0.52 to 0.55), TCF (r^2 from 0.51 to 0.53), and TCB (r^2 =0.47), as well as the thoracic and lumbar fat, carcass weight (r^2 from 0.51 to 0.66) and muscle tissue in the carcass (r^2 from 0.44 to 0.57), using *in vivo* measurements taken by ultrasonography between the 12th and 13th thoracic vertebrae and between the 3rd and 4th lumbar vertebrae, as well considering body weight or carcass characteristics in adult hair breed ewes (5,6). In the present study, only *in vivo* measurements taken between the 12th and 13th thoracic vertebrae were considered, since they showed higher correlation values than measurements taken between the 3rd and 4th lumbar vertebrae.

The present study demonstrates that it is possible to predict the carcass tissue composition in "Blackbelly" lambs, with moderate to high precision (r^2 > 0.71 ≤ and ≤ 0.78), using *in vivo* measurements of the DLDM with the carcass tissues (TCM and TCB) and the CCI. On the other hand, it has been possible to predict with satisfactory precision (r^2 from 0.74 to 0.91) the TCM, TCF, and TCB in the carcass of "Pelibuey" and "Katahdin" sheep breeds using *in vivo* biometric measurements (4). Similar results (r^2 from 0.57 to 0.93) have been shown in adult "Pelibuey" sheep (3). In this context, it can be seen that biometric measurements can be used with greater accuracy and precision than ultrasonography measurements to predict the carcass traits of hair sheep, but it is important to consider that the speed, precision, and reduced handling of the animals allowed by the use of ultrasound suggests an advantage of the latter over the use of biometric measurements.

On the other hand, Díaz et al. (8) analysed fattening and conformation measures as possible predictors of carcass tissue composition in suckling lambs (9-15 kg) of the "Manchega" breed, reporting that the LP and CL were correlated with the TCM and TCB (r ≥ 0.75 ≤ 0.87), while the LP was the variable that showed the highest correlation coefficients with TCF (r = 0.74). In the present study, by contrast, the LP showed no correlation with the weight of any of the carcass tissues (p>0.05). Likewise, the CL only correlated with the TCB (r=0.67, p≤0.05), which differs from the results obtained by Díaz et al. (8). The differences between the studies could be explained by two main factors: on the one hand, the biotype of the animal, since the "Manchega" breed is a dairy breed with greater bone development in relation to muscle development, while hair breeds such as the "Blackbelly" have another conformation, with a better muscle:bone ratio; additionally, the age or maturity of the animal can influence the differences between the two studies, since in a lamb of 9 to 15 kg the bone tissue has a higher proportion of fat with respect to live weight than a lamb of 25 to 30 kg as has been used in the present study. Given that carcass tissue composition is associated with animal growth and body weight (19,20), the predictive variables of tissue composition, and the equations generated from them, may vary according to the maturity or age and the biotype of the animal. In the present study, the CCI was the variable that was most correlated with the weight of the carcass tissues.

In this regard, Díaz et al. (8), reported that the CCI had the highest correlation coefficients, with TCM (r=0.90), TCB (r=0.77), and TCF (r=0.68). This may occur because both proportions involve a weight component highly correlated with the weight of the tissues.

Finally, the prediction equations for carcass tissue composition in our study present moderate to high precision and involve CCI, LP, and CL as predictors. Similarly, Díaz et al. (8) report that the CCI has a good predictive capacity for the tissue composition of the carcass, which indicates that the results of this study are in agreement with those reported by these authors (8).

In conclusion, the use of *in vivo* (taken by ultrasonography) and *postmortem* measurements allow for predicting the carcass tissue composition in "Blackbelly" lambs, since they provide prediction equations with moderate to high precision ($r^2 > 0.71 \leq$ and ≤ 0.78). This represents a useful tool for decision-making in sheep production systems regarding the optimal weight and age of slaughter in this breed, where the production of lean or muscular tissue with an adequate level of fat is maximised. Finally, we suggest continuing with this type of study considering larger sample size and other measurements on the carcass to verify the precision of ultrasonography.

Conflict of interests

The authors declare that they have no conflict of interest.

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