Ecosist. Recur. Agropec. 13(1): e4725, 2026
https://doi.org/10.19136/era.a13n1.4725

Evaluation of predictive models of carcass tissue composition in Black Belly sheep

Evaluación de modelos predictivos de la composición tisular de la canal en ovinos Black Belly

Dany Alejandro Dzib-Cauich[1], Ignacio Vázquez-Martínez[2], Miguel Ángel Gastelum-Delgado[2], Germani Adrián Muñoz-Osorio[3], Ricardo Alfonso Garcia-Herrera[2], Alfonso Juventino Chay-Canul[2]*

[1]Instituto Tecnológico Superior de Escárcega, Calle 85 entre 10b s/n Colonia: Unidad Esfuerzo Y Trabajo #1 CP. 24350 Escárcega, Campeche, México

[2]División Académica de Ciencias Agropecuarias. Universidad Juárez Autónoma de Tabasco, km 25. Carretera Villahermosa-Teapa, km 25, R/A. La Huasteca 2a Sección, Centro, Tabasco, México. CP. 86280. Villahermosa, Tabasco, México.

[3]Secretaria de Educación del Gobierno del Estado de Yucatán. Edificio Fénix, Mérida, Yucatán, México. CP. 97070, Mérida, Yucatán, México

*Correspondence author: alfonso.chay@ujat.mx

Scientific note

Received: August 10, 2025
Accepted: November 20, 2025

ABSTRACT. The objective of this study was to evaluate the suitability of predictive models based on the 9–11 rib section for estimating carcass tissue composition in Black Belly sheep. The 9–11 rib section was dissected into muscle, fat, and bone. The evaluation was performed using Model Evaluation Systems. Regression analysis showed that the intercepts differed from zero ($P < 0.05$), and the slopes did not differ from unity ($P > 0.05$). All models showed moderate to high accuracy (r^2 = 0.59–0.82). The muscle and bone models showed high accuracy (Cb = 0.94–0.99) and reproducibility (CCC = 0.76–0.90), while the fat model showed low accuracy and precision. These results indicate that the equations for muscle and bone reliably predict carcass composition in Black Belly sheep, although the fat model requires adjustment.
Key words: Carcass, hair sheep, mathematical models, prediction, rib section cut.

RESUMEN. El objetivo de este estudio fue evaluar la idoneidad de modelos predictivos basados en la sección 9-11de la costilla para estimar la composición tisular de la canal en ovinos Black Belly. La sección 9–11 de la costilla se disecó en músculo, grasa y hueso. La evaluación se realizó por medio del Model Evaluation Systems. El análisis de regresión mostró que los interceptos difirieron de cero ($P < 0.05$), y las pendientes no difirieron de la unidad ($P > 0.05$). Todos los modelos presentaron precisión moderada a alta (r^2 = 0.59–0.82). Los modelos de músculo y hueso mostraron alta exactitud (Cb = 0.94–0.99) y reproducibilidad (CCC = 0.76–0.90), mientras que el modelo de grasa presentó baja exactitud y precisión. Estos resultados indican que las ecuaciones para músculo y hueso predicen confiablemente la composición de la canal en ovinos Black Belly, aunque el modelo de grasa requiere ajuste.
Palabras clave: Canal, ovinos de pelo, modelos matemáticos, predicción, corte de costillas.

How to cite: Dzib-Cauich DA, Vázquez-Martínez I, Gastelum-Delgado MA, Muñoz-Osorio GA, Garcia-Herrera RA, Chay-Canul AJ (2026) Evaluation of predictive models of carcass tissue composition in Black Belly sheep. Ecosistemas y Recursos Agropecuarios 13(1): e4725. DOI: 10.19136/era.a13n1.4725.

Ecosist. Recur. Agropec. 13(1): e4725, 2026
https://doi.org/10.19136/era.a13n1.4725

INTRODUCTION

Although complete dissection of a sheep carcass enables determination of its tissue composition, this technique is laborious and expensive. The cost of conducting studies in this area is a limiting factor since evaluating carcass composition requires complete dissection of half a carcass (Marcondes *et al*. 2012). Furthermore, Marcondes *et al.* (2012) emphasised the importance of methodologies that can estimate carcass or body composition without sacrificing the entire carcass, highlighting their economic and temporal advantages. Silva *et al.* (2013) therefore suggest that the work involved in dissecting a carcass can be reduced by estimating its tissue composition using predictive models. Using predictive models could reduce the cost of experiments and provide an alternative approach.

In this sense, the 9–11th rib section is widely used as a representative sample of carcass composition in cattle and sheep because the proportions of muscle, fat and bone in this section closely reflect those of the whole carcass (Hankins and Howe 1946). Using the 9–11th rib section in sheep can therefore minimise carcass damage and enable precise prediction of tissue composition, reducing costs and labour (Escalante-Clemente *et al*. 2022; Quijano-Gallegos *et al.* 2025). However, most predictive equations have been developed and evaluated for cattle and other sheep breeds, so their applicability to tropical hair sheep, such as the Black Belly breed, is uncertain (Escalante-Clemente *et al*. 2022, Quijano-Gallegos *et al*. 2025). However, for these methods to be widely adopted, they would need to be sufficiently accurate. According to Tedeschi (2006), the adequacy of a model can only be assessed by combining statistical analysis with the model's intended purpose. It was also determined that identifying and acknowledging a model's deficiencies is the initial phase in enhancing its precision and dependability. Models are valuable tools for representing biological systems mathematically. Nevertheless, the utilisation of a representative sample is imperative to facilitate the estimation of precise and accurate values in a distinct population (Vargas *et al.* 2025). Prediction models are usually developed based on datasets obtained under specific production conditions and reflecting regional practices. Therefore, it is crucial to assess these models to validate the accuracy and precision of the estimated values in diverse environmental conditions, genotypes and management practices that are different to those for which the models were developed (Souza *et al*. 2016, Mehaba *et al.* 2025). Furthermore, evaluating models using independent data can reveal their robustness and provide a deeper understanding of the effects of the chosen parameters on prediction. This could facilitate their acceptance and recommendation (Oliveira *et al*. 2013). Evaluating models enables the identification of their strengths and weaknesses, as well as the detection of knowledge gaps and the impact of different datasets on the parameters used in the modelling approach and the model's performance (Mehaba *et al*., 2025). Therefore, the present study aimed to evaluate the adequacy of predictive models of carcass tissue composition in growing Black Belly sheep by using an independent database that included animals of a similar breed, sex, age, and body weight.

MATERIALS AND METHODS

The study was carried out at the Centro de Integración Ovina del Sureste (CIOS) in R/A Alvarado Santa Irene, 2nd Section, Centro Municipality, Tabasco, Mexico. This area has a humid tropical climate with temperatures ranging from 15 to 44 °C, averaging 26 °C. Sixteen six-month-old intact male Black Belly sheep with a body weight of 31.99 ± 2.38 kg were used. All animals were treated in accordance with the Academic Department of Agricultural Sciences′ guidelines and regulations for ethical animal experimentation at the Universidad Juárez Autónoma de Tabasco (CIEI: Folio 1173-2022). The animals were randomly selected from the fattening groups. They were fed a diet consisting of 80% concentrate and 20% forage, estimated to contain 15% crude protein (CP) and 12 MJ metabolizable energy (AFRC 1993), which was provided ad libitum. The diet included the following ingredients: 53% ground maize, 14% soybean meal, 20% star grass hay, 3% molasses, 4% rice flour, and a 1% premix of vitamins and minerals.

In accordance with the applicable standards (NOM-033-SAG/ZOO-2014 and NOM-088-SAG/ZOO-2014), the animals were slaughtered after fasting for 24 hours. After slaughter, the carcasses were chilled at 1 °C for 24 hours. Ribs 9–11 were removed from the left carcass, dissected into bone, fat, and muscle tissues, and weighed separately. The rest of the carcass was completely dissected into bone, fat and muscle. Finally, the weight of the rib 9–11 section was added to calculate the total carcass weight of muscle (TCM), fat (TCF) and bone (TCB).

Evaluation of predictive models

To evaluate the adequacy of the models proposed by Escalante-Clemente *et al*. (2022), an independent dataset of carcass and 9–11 rib section tissue composition from sixteen six-month-old intact male Black Belly sheep was used. The models evaluated were:

1.- TCM (kg) = 0.89 + 1.11 ×LHCW+ 24.49 × FRib

2.- TCF (kg) = -0.19 + 0.16 ×LHCW + 20.37 × FRib

3.- TCB = 0.58 + 0.28 ×LHCW + 9.32 × BRib

Where: TCM: Carcass muscle (kg); TCF: Carcass fat (kg); TCB: carcass bone (kg); FRib: fat in 9-11 rib section (kg); BRib: Bone in the 9^{th}-11^{th} rib section (kg); LHCW: left half-carcasses weight (kg).

The adequacy of the equations was assessed. The models' accuracy and precision were evaluated using a straightforward linear regression analysis of the observed values (Y) against the predicted values (X). The estimated carcass tissue compositions were then compared with the observed values using the following regression model: $Y = \beta_0 + \beta_1 \times X$. Where X = predicted value, Y = observed value, and β_0 and β_1 = intercept and slope of the linear equation. This was tested against the following statistical hypotheses: H_0: $\beta_0 = 0$, H_0: $\beta_1 = 1$, and Ha: not H_0. If the null hypotheses were not rejected, the prediction model accurately estimated the carcass tissue composition. The accuracy and precision of the models were assessed using the mean square error of prediction (MSEP), the concordance correlation coefficient (CCC), r^2 and graphical analysis. The MSEP was decomposed into three main sources of variation: (1) mean bias, which represents the central tendency of deviation; (2) systematic bias, which represents deviation from a slope of 1; and (3)

Ecosist. Recur. Agropec. 13(1): e4725, 2026
https://doi.org/10.19136/era.a13n1.4725

random error, which represents variation not explained by the regression (Tedeschi 2006). The CCC was used to assess model accuracy and precision simultaneously and was decomposed into a correlation coefficient estimate (ϱ), which estimates model precision, and a bias correction factor (Cb), which indicates accuracy. Additionally, the location shift, scale shift and standard deviation of the estimated CCC were calculated according to Lin (1989). The values of CCC, ϱ and Cb range from 0 to 1, with values close to 1 indicating precise and/or accurate models (Lin 1989, Tedeschi 2006). The coefficient of model determination (CD) was used to assess the variance of the predicted data. Coefficients greater than 0.80 were considered to indicate high precision and accuracy. Moderate precision and accuracy were assumed when the coefficients were between 0.51 and 0.79, and low precision and accuracy were assumed when the coefficients were below 0.50. All calculations were performed using the Model Evaluation System (Tedeschi 2006).

RESULTS AND DISCUSSION

Table 1 shows the mean, minimum and maximum values for carcass traits and 9–11 rib sections in Blackbelly sheep. The weight of the left half-carcass ranged from 6.20 to 8.90 kg. The muscle weight of ribs 9–11 (MRib) ranged from 0.07 to 0.14 kg. The fat content of sections 9–11 (FRib) ranged from 0.01 to 0.07 kg, while the bone content (BRib) ranged from 0.05 to 0.10 kg.

Table 1. Variables used to estimate carcass tissue composition for Black Belly sheep.

Variable	Description	Mean	SD	Minimum	Maximum
LHCW	left half-carcasses weight (kg).	7.62	0.87	6.20	8.90
WRib	Weight of 9th-11th rib section (kg)	0.21	0.03	0.17	0.26
MRib	Muscle in 9th-11th rib section (kg)	0.11	0.02	0.07	0.14
BRib	Bone in 9th-11th rib section (kg)	0.06	0.01	0.05	0.10
FRib	Fat in 9th-11th rib section (kg)	0.03	0.01	0.01	0.07
TCM	Carcass muscle (kg)	10.15	1.20	8.04	12.02
TCF	Carcass fat (kg)	2.39	0.60	1.46	3.12
TCB	Carcass bone (kg)	3.38	0.34	2.86	3.98

SE: standard deviation.

Regression analysis showed that the intercept (β0) differed from 0 in all models ($P < 0.05$; see Table 2). However, the slope (β1) did not differ significantly from 1 ($P > 0.05$). All models showed moderate to high precision ($0.59 \leq r^2 \leq 0.82$). The models for TCM and TCB had high accuracy (bias correction factor: $0.94 \leq Cb \leq 0.99$) and moderate to high reproducibility and agreement with the observed data (concordance correlation coefficient: $0.76 \leq CCC \leq 0.90$; see Figure 1). In contrast, the TCF model had low Cb and CCC values; in this model, the main component of the MSEP was mean bias (>75.93%). In the models for TCM and TCB, however, the main component of the MSEP was random error, indicating that only 3.22% and 4.22% of the error was associated with systematic bias for TCM and TCB, respectively. Additionally, both models (TCM and TCB) exhibited the greatest proximity to the identity line (Y = X; Figure 1). The CD value for the TCM model indicated underprediction (CD > 1), whereas for the TCB and TCF models, the CD value indicated overprediction (CD < 1). Nevertheless, an underprediction of 3% was observed in the TCM equations.

Table 2. Descriptive statistics of the relationships between observed and predicted carcass tissue composition for Black Belly sheep.

Variable[1]	Obs	TCM	Obs	TCF	Obs	TCB
Mean	10.15	10.16	2.39	1.71	3.38	3.26
SD	1.20	1.17	0.60	0.36	0.34	0.32
Minimum	8.04	8.26	1.46	1.10	2.86	2.78
Maximum	12.02	11.97	3.12	2.50	3.98	3.96
r^2		0.82		0.59		0.65
r		0.90		0.77		0.81
CCC		0.90		0.36		0.76
Cb		0.99		0.46		0.94
MEF		0.81		-0.77		0.52
CD		1.03		0.57		0.97
Regression analysis						
Intercept (β_0)						
Estimate		0.79		0.22		0.59
SE		1.19		0.48		0.53
P-value ($\beta_0 = 0$)		0.001		0.001		0.001
Slope (β_1)						
Estimate		0.92		1.26		0.85
SE		0.12		0.27		0.16
P-value ($\beta_1 = 1$)		0.50		0.35		0.37
MSEP source, % MSEP						
Mean bias		0.20		75.93		24.25
Systematic bias		3.22		1.45		4.22
Random error		96.57		22.62		71.53
Root MSEP						
Estimate		0.50		0.77		0.22
% of the mean		4.99		45.26		6.91

[1]Obs: observed evaluation data set; CCC: concordance correlation coefficient; ϱ = Correlation coefficient estimate (precision). Cb: bias correction factor; MEF: modelling efficiency; CD: coefficient of model determination; MSEP: mean square error of the prediction.

This study evaluates predictive models for carcass tissue composition through rib section characteristics 9–11 in Black Belly sheep, using an independent dataset. According to Tedeschi (2006), the usefulness of a model should be assessed in terms of its suitability for a particular purpose. Several tests are available to assess the adequacy of a model, ensuring impartiality in the decision-making process of accepting or rejecting its suitability. Furthermore, before developing new equations, it is essential to identify and accept the limitations of existing models. These models should be evaluated to identify their strengths and weaknesses, carefully considering constraints and possible improvements in describing the variable under study more accurately (Marcondes *et al*. 2010, Fonseca *et al*. 2015, 2017).

Ecosist. Recur. Agropec. 13(1): e4725, 2026
https://doi.org/10.19136/era.a13n1.4725

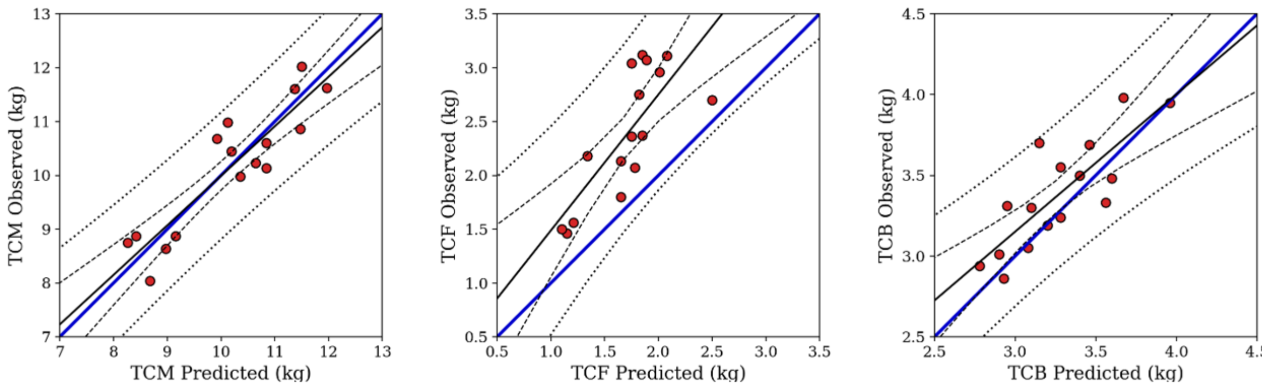

Figure 1. Relationship between the observed and predicted values of carcass tissues in Black Belly sheep. The solid line is Y = X, and the dotted line is the linear regression.

The evaluation of the predictive models developed by Escalante-Clemente *et al.* (2022) for predicting the carcass tissue composition of Black Belly lambs via rib dissection revealed that the TCM and TCB models exhibited moderate to high precision, with r^2 values of 0.82 and 0.65, and r values of 0.90 and 0.81, respectively. This yielded moderate to high CCC values (0.76 ≤ CCC ≤ 0.90) and high Cb values (0.94 ≤ Cb ≤ 0.99). This high level of accuracy demonstrates the adequacy of the models, as it is the most important measure of goodness of fit and represents the models' ability to predict actual values (Tedeschi 2006). Moreover, in the TCM and TCB models, random error was the main component of the MSEP (96.57% and 71.28%, respectively). A high proportion of MSEP in random error is desirable as it helps to avoid high proportions of MSEP in systematic and mean bias. It also indicates that most of the variation in the results is due to random effects rather than problems with the equation (Silva *et al*. 2019, Quijano-Gallegos *et al*. 2025). On the other hand, the TCF model exhibited a moderate r^2 value of 0.59 and r values of 0.77, as well as low CCC (0.36) and Cb values (0.46), indicating low precision and accuracy. The MSEP partition also showed that mean bias was the component of error that most affected the TCF model (over 75.93%). This confirms that the model was deemed adequate for prediction due to the mean bias, as the errors are mostly concentrated around the mean (Fonseca *et al.* 2015). The performance of the TCF model may be due to the complex nature of fat content storage in an animal's body, given that fat is the most variable and labile tissue in the body (Tedeschi *et al*. 2013, Fonseca *et al.* 2015).

In this sense, Quijano-Gallegos *et al*. (2025) evaluated the applicability of the predictive models of Escalante-Clemente *et al*. (2022) in Dorper lambs. They found that the models provided inaccurate estimates and were unable to predict carcass tissue composition. The authors also highlighted limitations in the equations used to estimate carcass composition in Dorper lambs, with poor agreement between observed and predicted weights. This emphasises the importance of developing more accurate models that consider breed, sex and local rearing conditions (Neves *et al*. 2018, Quijano-Gallegos *et al*. 2025). The results indicate that the TCM and TCB models have great potential for predicting the amount of muscle and bone in the carcass of growing intact male Black Belly, with moderate precision and very high accuracy. However, TCF model had low precision and accuracy.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

LITERATURE CITED

AFRC (1993) Technical Committee on Responses to Nutrients. Energy and protein requirements of ruminants. CAB International, Wallingford, UK. 129 p.

Escalante-Clemente S, Vázquez-Jiménez S, López-Durán S K, Arcos-Alvarez DN, Arbez-Abnal TA, Piñeiro-Vazquez ÁT, Muñoz-Benítez AL, Vargas-Bello-Pérez E, Chay-Canul AJ (2022) Using the 9th–11th rib section to predict carcase tissue composition in Blackbelly sheep. Italian Journal of Animal Science 21(1): 161-167.

Fonseca MA, Tedeschi LO, Valadares Filho SC, De Paula NF, Silva LD, Sathler DFT (2017) Evaluation of equations to estimate body composition in beef cattle using live, linear and standing-rib cut measurements. Animal Production Science 57(2): 378-390. http://dx.doi.org/10.1071/AN15312

Fonseca MA, Valadares Filho SC, Tedeschi LO, Chizzotti ML, Machado MG, Abreu DC (2015) Evaluation of predictive equations developed to assess body composition of F1 Nellore× Angus bulls and steers. Animal Production Science 55(8): 978-987. http://dx.doi.org/10.1071/AN13439

Hankins OG, Howe PE (1946) Estimation of the composition of beef carcasses and cuts. Technical Bulletin. 926. USDA, Washington, DC. pp. 1-19.

Lin LI (1989) A concordance correlation-coefficient to evaluate reproducibility. Biometrics 45: 255-268.

Marcondes MI, Tedeschi LO, Valadares Filho SC, Chizzotti ML (2012) Prediction of physical and chemical body compositions of purebred and crossbred Nellore cattle using the composition of a rib section. Journal of Animal Science 90(4): 1280-1290. https://doi.org/10.2527/jas.2011-3839

Mehaba N, Schrade S, Eggerschwiler L, Dohme-Meier F, Schlegel P (2025) Accuracy and precision in DM intake prediction models for lactating dairy cows. Animal 101535. https://doi.org/10.1016/j.animal.2025.101535

Neves MLMW, Souza EJO, Véras RML, Valadares Filho SC, Marcondes MI, Silva GS, Barreto LMG, Ferreira MA, Véras ASC (2018) Can the body composition of crossbred dairy cattle be predicted by equations for beef cattle?. Asian-Australasian Journal of Animal Science, 31, 10: 1604-1610. https://doi.org/10.5713/ajas.17.0876

Oliveira AS, Abreu DC, Fonseca MA, Antoniassi PMB (2013) Short communication: Development and evaluation of predictive models of body weight for crossbred Holstein-Zebu dairy heifers. Journal of Dairy Science 96: 6697-6702. https://doi.org/10.3168/jds.2013-6988

Quijano-Gallegos EJ, Vázquez-Martínez I, Meza-Villalvazo VM, Gastelum-Delgado MÁ, Orzuna-Orzuna JF, Muñoz-Osorio GA, Marcondes MI, Chay-Canul AJ (2025) Can equations for Black Belly lambs be used to predict the carcass tissue composition of Dorper lambs? Agro Productividad. 235-241. https://doi.org/10.32854/1653s096

Silva AL, DeVries TJ, Tedeschi LO, Marcondes MI (2019) Development of equations, based on milk intake, to predict starter feed intake of preweaned dairy calves. Animal, 13(1), 83-89. https://doi.org/10.1017/S1751731118000666

Silva LC, Valadares Filho SC, Detmann E, Marcondes M I, Rotta PP, Prados LF, Zanetti D (2013) Evaluation of equations to predict body composition in Nellore bulls. Livestock Science, 151(1): 46-57. https://doi.org/10.1016/j.livsci.2012.09.014

Souza VL, Drackley JK, Almeida R, Bittar CMM, Albertini TZ, Morrison SY, Lanna DPD (2016) Evaluation of nutrition models to estimate performance of young dairy calves: a meta-analytical study under tropical conditions. Animal 10: 1965-1974. https://doi.org/10.1017/S1751731116000975.

Tedeschi LO, Fox DG, Kononoff PJ (2013) A dynamic model to predict fat and protein fluxes associated with body reserve changes in cattle. Journal of Dairy Science 96: 2448-2463. https://doi.org/10.3168/jds.2012-6070

Tedeschi LO (2006) Assessment of the adequacy of mathematical models. Agricultural Systems 89: 225-247. https://doi.org/10.1016/j.agsy.2005.11.004

Vargas J, Swenson M, Schilling-Hazlett AK, Reis IA, Velasquez C, Martins EC, Sitorski L, Campos LM, Carvalho PHV, Stackhouse-Lawson KR, Place SE (2025) Evaluation of models of enteric methane emissions in finishing steers. Animal 101536. https://doi.org/10.1016/j.animal.2025.101536