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Using ultrasound for renal fat thickness measurements to predict body fat in Dorper ewe lambs

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ABSTRACT: This study determined the relationship between kidney fat thickness (KFT), measured by ultrasound, and body fat depots in Dorper ewe lambs. Twenty ewe lambs of six months of age (body weight 36.53±25 kg) were used. The subcutaneous fat thickness (SFT), depth (LTD, cm), width (LTW, cm), and area (LTMA, cm^2) of the *longissimus thoracis* muscle and KFT were measured by ultrasound 24 h before slaughter. After slaughtering, the carcass weight (HCW) was recorded. The carcass was then chilled for 24 hours at a temperature of 1°C and reweighed (CCW), halved along the dorsal midline. The left half of the carcass was dissected into muscle, fat (subcutaneous fat plus intermuscular fat, CF), and bone, and each of these tissues was weighed separately and adjusted to give the total weight of the carcass. Internal fat (IF) was removed, weighed, and categorized as mesenteric (MF), omental (GO), or perirenal (GP) fat deposits. Total IF weight was the sum of these depots. The total weight of total body fat (TBF) was calculated as the sum of the IF plus the CF. KFT ranged from 0.27 to 0.80 cm. Similarly, the TBF ranged from 2.41 to 6.38 kg. KFT was moderately associated with internal fat stores ($0.65 \leq r \leq 0.79$, $P < 0.001$). In addition, PLT and ALT had a low level of association with CF. The results showed that KFT had a moderate association with internal body fat ($0.65 \leq r \leq 0.79$, $P < 0.001$). However, it was weakly associated with CF (r=0.42). All equations had low to moderate precision ($0.57 \leq r2 \leq 0.81$). However, all equations had high accuracy (bias correction factor > 0.94). It is also important to note that Dorper lambs in this study tended to store more fat in the carcass than in the internal depots. The results of this study support the use of KFT as a non-invasive method for predicting body fatness in hair sheep.

Keyword: *longissimus thoracis* muscle; models of prediction; renal fat thickness; body fat; carcass yield.

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INTRODUCTION

Body fat deposition in farm animals has a major impact on carcass yield and consumer perception of meat quality (Schumacher et al., 2022; Muñoz-Osorio et al., 2024). An understanding of the effects of livestock production practices on fat deposition and the molecular mechanisms involved will lead to a better understanding of livestock finishing diets (Schumacher et al., 2022). It has also been highlighted that the accumulation of fat reserves in the body is positively related to total body energy, which in turn represents a large proportion of energy expenditure (Morales-Martinez et al., 2020; Gastelum-Delgado et al., 2024). The accumulation of energy stores is also an important adaptation in migratory animals to survive in a seasonal environment (Denryter et al., 2022). The extent to which animals can accumulate energy stores is underpinned by elements of the animal's endogenous and exogenous nutritional environment. Endogenously, the amount of fat that an animal can accumulate depends on the nutritional status (i.e., the level of body fat stored) and nutritional requirements (e.g., lactation, growth) (Denryter et al., 2022).

Post-mortem whole-body chemical fat analysis is the definitive measure of total body fat content in sheep. However, accurate objective measurement of body fat content in live sheep is desired in several agricultural and experimental situations, including as a tool for reproductive and growth management and for predicting total carcass lean/fat content (Kenyon et al., 2014; Miller et al., 2018). Scientists have used equations to predict carcass composition and estimate fat deposition in several species (Schumacher et al., 2022). It has been reported that ultrasound measurements (USM) have great potential for predicting carcass composition in live sheep, and the information can contribute to selection programs (Schumacher et al., 2022; Van Der Merwe et al., 2022; Muñoz-Osorio et al., 2024). The USM can describe the carcass characteristics of hair sheep, and, from a practical point of view, these measurements are faster, easier to record, and easier for the animal to handle (Ramos-Ramos et al., 2024).

However, few studies have evaluated the potential of USM to predict body fat (subcutaneous and abdominal) (Morales-Martinez et al., 2020; Gastelum-Delgado et al., 2024). Previously, Morales-Martínez et al. (2020) highlighted the need for the development of accurate and non-invasive methods for the assessment of body and carcass fat deposition in live animals. Similarly, Van Der Merwe et al. (2022) stated that USM can be used to predict carcass merit at a given age and weight to enable the development of predictive models. It is therefore important for producers to slaughter lambs ideally following market specifications for the degree of fatness of the lambs. This will ensure optimum profitability throughout the market chain and high consumer acceptance (Van Der Merwe et al. 2022; Muñoz-Osorio et al., 2024).

Ultrasound measurement of renal fat thickness (KFT) is an attractive tool for studying body fat deposition in hair sheep breeds (Morales-Martínez et al., 2020; Gastelum-Delgado et al., 2024). The KFT has been evaluated as a predictor of body fat deposition in Pelibuey and Katahdin sheep (Morales-Martínez et al., 2020; Gastelum-Delgado et al., 2024), but to date, no studies have been conducted using USM to predict body fat deposition in the Dorper breed. The Dorper breed was developed in South Africa and is now being used in many tropical countries as a pure breed or in crosses with local breeds to improve sheep meat production (Ojango et al., 2023). The Dorper breed is known as an early maturing breed and has high fat content at a young age or a lower body weight (Cloete et al., 2000).

Today, few studies have investigated the ability of this breed to accumulate and distribute body fat. Therefore, this study determined the relationship between renal fat thickness measured by ultrasound and body fat reserves in Dorper ewe lambs.

MATERIALS AND METHODS

Animals and location

The study was conducted at the Centro de Integración Ovina del Sureste (CIOS), located in R/a Alvarado Santa Irene 2nd section, in the municipality of Centro, with a humid tropical climate and temperatures between 15 and 44 °C, with an average of 26 °C, Tabasco, Mexico. Animals used in this study were treated according to the Ethical Guidelines and Regulations for Animal Experimentation of the Agricultural Faculty of the Juárez Autonomous University (CIEI: Folio 1173-2022). Twenty-six-month-old Dorper ewe lambs with an average live weight (BW) of 36.53±25 kg were used. The animals were selected from the fattening groups when they reached slaughter body weight.

Slaughter and body fat depot measurements

The animals were slaughtered after a 24-hour fasting period, following current Mexican standards, and the live weight (BW) of the animals was recorded before slaughter. After slaughter, the carcass was weighed (HCW) and chilled for a period of 24 h at 1°C. Subsequently, it was weighed again (CCW) and divided by the dorsal midline into two halves. The left half carcass was dissected into muscle, fat, and bone, and each tissue was weighed separately. The weights of fat (subcutaneous fat plus intermuscular fat), muscle, and bone were adjusted to the total carcass weight. Viscera (liver, heart, kidneys, lungs) were separated and weighed. Internal fat (IF, internal fat depot) was dissected, weighed, and grouped as mesenteric (MF), omental (OF), or perirenal (PF) fat depots. These three depots were summed to obtain the total weight of the internal fat depot (IF). Carcasses were dissected that same day in a climate-controlled room at approximately 24°C in DACA-UJAT's Meat Products Technology Laboratory. The gastrointestinal tract (GIT) was weighed, rinsed with water, and weighed again. The shrunk body weight (SBW, kg) at slaughter minus the GIT content was used to calculate the empty BW (EBW).

Ultrasound measurements

Ultrasound (USM) measurements were recorded 24 h before slaughter. Subcutaneous fat thickness (SFT) and the depth (DLT, cm), amplitude (ALT, cm), and area (ARLT, cm^2) of the *longissimus thoracis* muscle were determined using a Mindray DP Vet 50® real-time B-mode ultrasound device (Mindray Ltd. and National Ultrasound Inc.; Wuxi, Jiangsu, China) with a 7.5 MHz linear probe (Morales-Martínez et al., 2020). In addition, ultrasound renal fat thickness (KFT) was measured according to the methodology described by Morales-Martinez et al. (2020) (Figure 1).

Data analyses

Descriptive statistical analysis was performed using the PROC MEANS procedure in SAS (SAS Inst. Inc., Cary, NC, 2010). In addition, correlation coefficients between variables were estimated using PROC CORR (SAS Inst. Inc., Cary, NC, 2010). Each variable was tested for normal distribution using the Shapiro-Wilk test with PROC UNIVARIATE (SAS Inst. Inc., Cary, NC, 2010). Regression analysis hypotheses were tested for standard deviation (normality plots), homogeneity of variance (residual plots), multicollinearity (variance inflation factors and tolerance), and autocorrelation (Durbin-Watson [DW] test). The PROC REG command was used for regression analysis (SAS Inst. Inc., Cary, NC, 2010). STEPWISE and Mallow's Cp options for the SELECTION statement were used to select variables for this model. The coefficient of determination (r^2), mean squared error (MSE), and root mean square of MSE (RMSE) were used to calculate the accuracy of the models.

Model evaluation

In addition, the best models (high r^2 and low MSE and RMSE) were assessed for their adequacy. The

Figure 1. Ultrasound image of the three measurements of renal fat thickness behind the 13th rib on the right side of the kidney.

accuracy and precision of the models were assessed by simple linear regression analysis of the observed values (Y) with the predicted values (X). The following procedures were used graphical analysis, mean square of prediction error (MSPE), decomposition of MSPE into three sources of error (error due to bias, error due to the slope of the regression between observed and predicted values being different from 1, and random error), concordance correlation coefficient (CCC) and its decomposition into precision (ρ, correlation coefficient) and accuracy (Cb, bias correction factor) indicators. High precision and accuracy were assumed when the coefficients were > 0.80. Moderate precision and accuracy were assumed when the coefficients were > 0.51 and < 0.79, and low precision and accuracy were assumed when the coefficients were < 0.50. Finally, the Model Evaluation System (Tedeschi, 2006) was used for all calculations.

RESULTS

The descriptive statistics of the ultrasound measurements and the deposition of body fat are shown in Table 1. The BW ranged from 21.00 to 36.25 kg, while the KFT ranged from 0.27 to 0.80 cm. Similarly, the range for TBF was 2.41 to 6.38 kg. KFT was moderately associated with internal body fat stored ($0.65 \le r \le 0.79$, $P < 0.001$). However, it had a low association with CF ($r = 0.42$). In addition, LTD and LTA had a low relationship with CF, with a negative and a positive relationship, respectively (Figure 2). Table 2 shows the regression equations developed to predict body fat depots. For each body fat depot, two equations were obtained. The r^2 ranged from 0.58 to 0.70 ($P < 0.001$; Table 2) for internal body fat depots (MF, OF, and PF). The equations for the prediction of IF and CF had an r^2 of 0.57 and 0.81 ($P < 0.001$). The equation for TBF had an r^2 of 0.73 ($P<0.001$). The variables included in the models were EBW, LTA, and KFT ($P < 0.05$).

All equations had low to moderate precision ($0.57 \le r^2 \le 0.81$; Table 3) when evaluating the developed equations (Table 3; Figure 2). However, all equations had high accuracy (bias correction factor > 0.94; Table 3). This confirms a moderate to high reproducibility index and agreement with the observed data ($0.72 \le CCC \le 0.88$; Figure 2). In all equations, the main component of the MSEP was random error (> 88.60%). This is an unexplained variance that cannot be accounted for by linear regression. Finally, regression analysis showed that the slope was not different from unity ($P>0.05$). However, the intercept was different from zero ($P<0.05$).

DISCUSSION

Previously, in male Pelibuey sheep, the KFT was highly correlated with the internal fat stores (0.78

Table 1. Descriptive statistics for USM and body fat depots in Dorper ewe lambs.

Abbreviature	Description	Mean	SD	Minimum	Maximum
SBW	Shrunk body weight (kg)	29.04	4.04	21.00	36.25
EBW	Empty body weight (kg)	25.46	4.03	17.66	33.58
LTD	*longissimus thoracis* muscle depth (cm)	2.14	0.43	1.29	3.54
LTA	*longissimus thoracis* muscle width (cm)	3.46	0.33	2.25	3.72
LTMA	*longissimus thoracis* muscle area (cm^2)	4.84	0.48	3.84	5.67
SFT	Subcutaneous fat thickness (cm)	0.25	0.05	0.13	0.35
KFT	kidney fat thickness (cm)	0.51	0.14	0.27	0.80
MF	Mesenteric fat (kg)	0.51	0.22	0.16	0.88
OF	Omental fat (kg)	0.48	0.27	0.16	1.15
PF	Pelvic fat (kg)	0.32	0.20	0.09	0.75
IF	Internal fat (kg)	1.30	0.61	0.64	2.70
CF	Carcass fat (kg)	2.51	0.50	1.64	3.68
TBF	Total body fat (kg)	3.81	1.01	2.41	6.38

SD: standard deviation

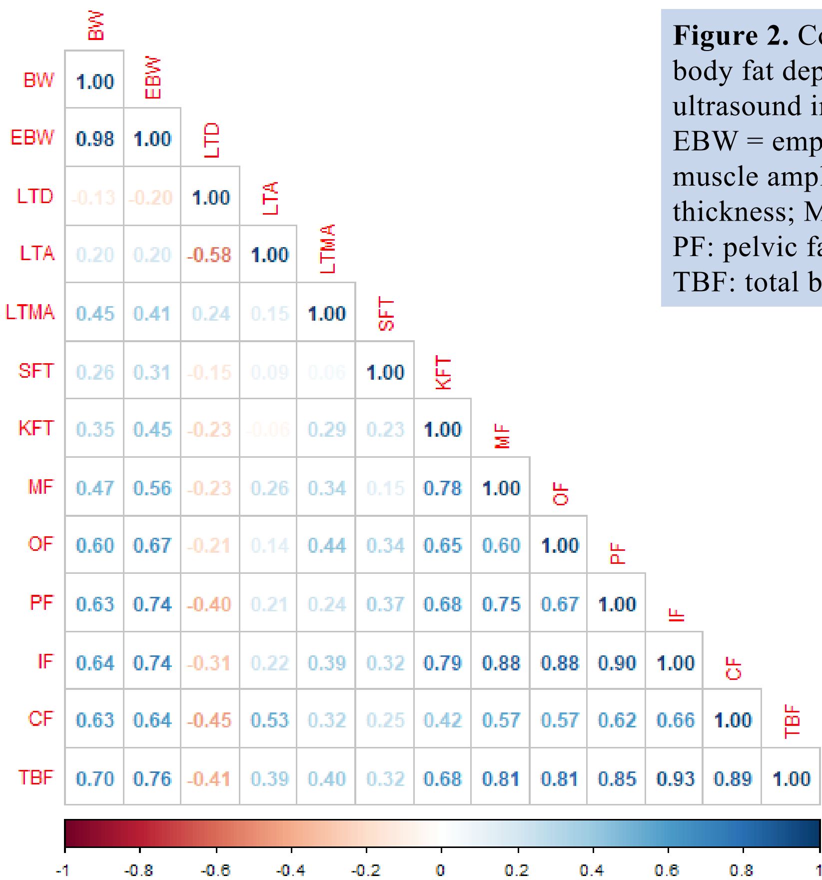

Figure 2. Correlation coefficients between body fat depots and renal fat measured by ultrasound in Dorper lambs. BW: body weight; EBW = empty BW; LTA: *longissimus thoracis* muscle amplitude; KFT: ultrasound kidney fat thickness; MF: mesenteric fat; OF: omental fat; PF: pelvic fat; IF: internal fat; CF: carcass fat; TBF: total body fat.

Table 2. Regression equations for prediction of body fat in Dorper ewe lambs

No.	Equation	R^2	MSE	RMSE	P-value
1	MF (kg) = -0.13 (±0.12*) + 1.25 (± 0.23***) × KFT	0.60	0.02		<.0001
2	MF (kg) = -0.84 (±0.33*) + 0.20 (± 0.08*) × LTA + 1.27 (± 0.21***) × KFT	0.70	0.01		<.0001
3	OF (kg) = -0.66 (±0.30*) + 0.04 (±0.01***) × EBW	0.55	0.04		0.0013
4	OF (kg) = -0.77 (±0.26*) + 0.03 (±0.01***) × EBW+ 0.86 (± 0.33*) × KFT	0.60	0.03		0.0004
5	PF (kg) = -0.19 (±0.13*) + 1.00 (±0.26***) × KFT	0.54	0.02		0.0011
6	PF (kg) = -0.75 (±0.28*) + 0.02 (±0.001*) × BW+ 0.89 (± 0.23*) × KFT	0.58	0.019		0.0006
7	IF (kg) = -0.51 (±0.34*) + 3.53 (±0.64***) × KFT	0.62	0.14		<.0001
8	IF (kg) = -1.89 (±0.41***) + 0.07 (±0.02***) × EBW + 2.57 (±0.52***) × KFT	0.81	0.07		<.0001
9	CF (kg) = 0.50 (±0.57*) + 0.08 (±0.02**) × EBW	0.40	0.15		0.0025
10	CF (kg) = -1.39 (±0.89*) + 0.07 (±0.02**) × EBW+ 0.63 (±0.24*) × LTA	0.57	0.11		0.0007
11	TBF (kg) = -1.06 (±0.98*) + 0.19 (±0.04***) × EBW	0.58	0.45		<.0001
12	TBF (kg) = -1.47 (±0.83*) + 0.14 (±0.03**) ×EBW+ 3.14 (±1.05**) × KFT	0.73	0.31		<.0001

"*" for P<0.05, "**" for P<0.01, and "***" for P<0.001.
BW: body weight; EBW = empty BW; LTA: *longissimus thoracis* muscle amplitude; KFT: ultrasound kidney fat thickness; MF: mesenteric fat; OF: omental fat; PF: pelvic fat; IF: internal fat; CF: carcass fat; TBF: total body fat.

Table 3. Mean and descriptive statistics of the accuracy and precision of the best equations for the prediction of body fat deposition in Dorper ewe lambs by means of ultrasound measurement of renal fat thickness.

Variable[1]	[Eq. 2]	[Eq. 4]	[Eq. 6]	[Eq. 8]	[Eq. 10]	[Eq. 12]
Mean	0.50	0.43	0.29	1.20	2.57	3.70
SD	0.18	0.20	0.16	0.53	0.38	0.84
r^2	0.69	0.60	0.62	0.81	0.57	0.75
CCC	0.82	0.73	0.76	0.88	0.72	0.83
ρ	0.83	0.77	0.78	0.90	0.75	0.85
Cb	0.98	0.94	0.96	0.97	0.95	0.97
Regression analysis						
Intercept (β_0)						
Estimate	-0.001	0.02	0.03	0.06	-0.01	0.03
SE	0.08	0.09	0.05	0.15	0.52	0.56
P-value ($\beta_0 = 0$)	0.001	0.001	0.001	0.001	0.001	0.001
Slope (β_1)						
Estimate	1.00	1.03	0.96	1.02	0.98	1.01
SE	0.15	0.19	0.17	0.11	0.19	0.14
P-value ($\beta_1 = 1$)	0.95	0.86	0.82	0.86	0.92	0.89
MSEP source, % MSEP						
Mean bias	0.08	5.75	5.03	11.18	3.50	4.35
Systematic bias	0.02	0.15	0.27	0.22	0.05	0.09
Random error	99.89	94.10	94.70	88.60	96.45	95.55
Root MSEP						
Estimate	0.11	0.17	0.12	0.27	0.32	0.52
% of the mean	23.36	39.36	43.47	22.78	12.56	14.30

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

$\leq r \leq 0.91$, $P < 0.001$). Furthermore, KFT explained between 61% and 84% of the internal fat variation. These results suggest that the variation in IF in the finishing of male Pelibuey lambs can be explained by the ultrasound KFT (Morales-Martínez et al., 2020). Similarly, Gastelum-Delgado et al. (2024) reported that KFT was moderately to strongly associated with internal body fat stores in fattening Katahdin lambs ($0.63 \leq r \leq 0.83$, $P < 0.001$). IF and CF had r values of 0.76 and 0.86, respectively (P<0.001). It is also reported that the KFT explained 43 % and 67 % of the variation in the PF and OF, respectively. For CF and TBF, they explained 54% and 56% of the variation, respectively, in finishing Katahdin lambs. Recently, Garcia-Cigarroa et al. (2024) found in crossbred ewes that, except for CF and KFT, other body fat depots showed low to moderate correlations (0.44 $\leq r \leq 0.75$, $P < 0.05$). These results are in agreement with those obtained in the present study. Since CF was the body fat depot less correlated with KFT. Regarding internal fat depots, Garcia-Cigarroa et al (2024) obtained regression equations to predict body fat stores with an r^2 ranging from 0.44 for PF to 0.87 for MF. The models included BW, LTMA, and KFT as predictors ($P < 0.05$). The equations had an r^2 ranging from 0.53 for CF to 0.81 for IF, and the predictors were EBW, LTMA, and KFT for the main fat stores, IF, CF, and TBF.

Due to differences in maturity, lambs of different breeds or sexes must be slaughtered at different live weights to produce carcasses of similar quality (Van Der Merwe et al., 2022; Muñoz-Osorio et al., 2024). In this sense, it has been reported that animal age, carcass weight, and subcutaneous fat thickness (SFT) are the main determinants of lamb carcass value (Van Der Merwe et al., 2022; Muñoz-Osorio et al., 2024). USM of SFT of the *longissimus thoracis* and *lumborum* muscles at the 12th and 13th thoracic vertebrae and KFT in growing lambs have shown that suitable regressions can be developed to predict carcass fatness at a given age or live weight of animals (Hopkins et al., 2008; Van Der Merwe et al., 2022; Gastelum-Delgado et al., 2024; Muñoz-Osorio et al., 2024). USM of fat thickness and *longissimus thoracis* muscle characteristics can help predict fat deposition rates of different breeds to determine ideal slaughter weights and optimize profitability and productivity in intensive lamb production systems (Van Der Merwe et al., 2022; Gastelum-Delgado et al., 2024; Garcia-Cigarroa et al., 2024).

On the other hand, the regression analysis showed that the slope was not different from unity ($P > 0.05$). However, the intercept was different from zero ($P<0.05$), an indication that the models tended to be parallel to the Y=X line (Tedeschi, 2006). This analysis indicated that adjustments were required to estimate the true value, although the model could be used to predict body fat deposition in Dorper ewe lambs. The equations showed low to moderate precision ($0.57 \leq r^2 \leq 0.81$), high accuracy (bias correction factor > 0.94), and moderate to high reproducibility index and agreement with observed data (concordance correlation coefficient of $0.72 \leq$ CCC ≤ 0.88) for predicting body fat deposition in Dorper ewe lambs. In all equations, the main component of the MSEP was random error (> 88.60%). This indicates that further evaluation is required to ensure that there is no lack of fit, i.e., simply random variation that cannot be accounted for by the model in its current form. In this study, Dorper lambs tended to store more carcass fat than they did in the internal carcasses. This may be directly related to the quality of the carcasses and meat of these animals. Therefore, knowing how and where fat gets stored in different breeds of sheep is important.

CONCLUSIONS

Under the conditions of the study and based on the obtained data, the proposed models were able to predict body fat deposition in Dorper ewes with moderate precision and good accuracy. The results of this study support the use of KFT as a non-invasive method for the prediction of body fatness in hair sheep lambs.

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CONFLICT OF INTEREST

None declared.

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