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The relationship of ultrasound measurements taken from two different anatomical regions to carcass traits and chemical composition of the carcass in Karayaka lambs

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Abstract: This study was undertaken to determine the relationship between carcass traits and chemical compositions. Using ultrasound scanning from two different anatomic regions, the study involved estimating carcass traits and chemical composition in male Karayaka lambs. Measurements were taken of skin thickness, subcutaneous fat thickness, muscle depth, muscle width, and muscle area between the 12th and 13th thoracic vertebrae (12–13T) and 3rd and 4th lumbar vertebrae (3–4L) using real-time ultrasound in 15 six-month-old lambs. The lambs were slaughtered after the ultrasound measurements, and then their warm and cold carcass weights; dressing percentage; bone, meat, and fat amounts; and chemical composition in terms of crude protein, fat, dry matter, and ash ratios were determined. The subcutaneous fat thickness measured with ultrasound from both locations had a high correlation with live weight, warm and cold carcass weight, carcass bone ($P < 0.01$), and carcass meat ($P < 0.05$) weights. The adjusted R^2 in the regression equation determined to estimate carcass traits using ultrasound yielded values of 50%–94% at 12–13T and 49%–83% at 3–4L ($P < 0.05$). As a result, it was determined that carcass traits were related to ultrasound measurements and that it is possible to predict carcass traits using live weight and ultrasonic skin thickness, muscle width, and muscle area.

Key words: Carcass meat, carcass weight, crude protein, lambs, ultrasound, skin thickness

1. Introduction

Sheep breeding is very important to the feeding and subsistence of the populace in arid regions with large meadows and pasture lands. It has provided humans with meat, milk, wool, and skin for millennia, while the idea of meat as the main product in sheep-farming is becoming increasingly popular. Sheep are mostly cultivated for their milk in many Mediterranean and East European countries (1), but mainly for lamb meat production in Turkey.

In recent years, the demand for low-fat meat has increased in many countries around the world (2), and breeding studies have been focused on changing carcass composition according to this demand (3). Breeders have not only had to increase meat yield but also produce low-fat meat to meet consumer demand. Previously, breeding studies to estimate meat yield and carcass composition had been based on subjective methods, like carcass grading with conformation information after slaughtering (4). However, in order to supply the increasing demands of both consumers and breeders, the use of quicker, more efficient, and objective methods (real-time ultrasound) is becoming more common (4,5). Nowadays, real-time ultrasound technology is widely used in breeding programs aimed at meat quality; it is a technology that is increasingly used to define meat quality and to obtain estimation parameters (3). Real-time ultrasound is a noninvasive technique used to determine carcass traits and composition based on the depth (ULD), width (ULW), and area (ULA) of the *Longissimus thoracis et lumborum* muscle, the subcutaneous fat thickness around the muscle (UFT), and its skin thickness (UST) (6,7). It is relatively difficult to take ultrasound measurements in sheep due to the soft and loose outer layer of subcutaneous fat and the fleece wool (5,8). Therefore, different anatomical regions have been measured to accurately estimate carcass traits and composition, from the 6th thoracic vertebrae to the 3rd coccyges (2,6–10).

Sheep are bred extensively in Turkey, where they have an important place in the meat production sector. About 90% of the sheep bred in Turkey are native breeds, including Karayaka sheep, which originate from the Asiatic mouflon (*Ovis vignei*). Karayaka are widely herded on the coastline

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of the Black Sea region, where there is a total population of approximately 1,000,000 sheep, some 3%–4% of the total sheep population of the country (11).

The present study was performed to determine the relationship between carcass traits and chemical compositions, and to estimate the carcass traits and chemical composition in male Karayaka lambs using ultrasound scanning from two different anatomical regions.

2. Materials and methods

This study, which was approved by the Animal Studies Ethics Committee of Ondokuz Mayıs University in Samsun, Turkey (approval number: HADYEK/29), was carried out on a private farm in Tekkeköy District of Samsun Province in northern Turkey. The farm is located at 41°12′N, 36°27′E at an elevation of 380 m. A total of 15 six-month-old male Karayaka lambs were used, with no changes made in the feeding or care of the lambs and the farm conditions maintained. The lambs were fed dry hay and 150 g of lamb starting feed (18% crude protein, 11.72 MJ/kg of ME) in addition to mother's milk from 3 months to weaning. The lambs were weaning from the milk at 3 months of age. After weaning, the lambs were grazed in a meadow during daylight hours and fed 200 g of lamb growth feed (16% crude protein, 10.88 MJ/kg of ME) in the evening. The lambs were kept away from adults using holding pens with a ground area of 0.4 m^2 until weaning and 0.6 m^2 from 3 to 6 months. The 15 lambs chosen for the study were removed from the herd at 6 months of age and weighed with a digital scale sensitive to 50 g; the mean weight value was determined as 36.61 ± 6.02 kg.

2.1. Ultrasound measurements

The ultrasound measurements were performed with a portable real-time ultrasound device (Aloka SSD-500) with a 3.5-MHz, 12.5-cm linear transducer. Wool was sheared from the measurement areas before RTU image acquisition, and the lambs were manually immobilized and acoustic gel was applied to provide good contact between the probe and the skin. Following physical palpation and preparation, the transducer was placed between the 12–13T and 3–4L, lateral and parallel to the vertebral column. All measurements were taken on the left side, 4 cm from the vertebral column. After capturing the scan image, the depth, width, and area of muscle; thickness of skin; and subcutaneous fat thickness at that point were measured with the electronic calipers (resolution: 0.1 cm) of the scanner. The area of muscle was measured with ultrasound on live animals on the same image after the borders of the muscle had been drawn (4,12).

2.2. Carcass traits

After ultrasound measurements were completed, the male lambs were not fed in the 12 h immediately before slaughter for determination of the carcass traits and carcass chemical composition. The lambs were cut according to the commercial cutting process, and the fore and hind limbs were then separated at the radiocarpal and tarsometatarsal articulations, respectively. The head, hide, and all internal organs were removed and the warm carcass weight was determined. Cold carcass weights were recorded after chilling at 4 °C for 24 h. Dressing percentages were determined from the live weights taken before slaughter and from the carcass weights after chilling for 24 h. The carcasses were symmetrically halved and the left side was jointed according to the procedure of Colomer-Rocher et al. (13) into primal cuts, namely the leg, foreleg, back, loin, neck, and breast+flank. All of the lambs' back sections were weighed separately. After weighing, the sections were separated into dissectible meat, bone, and fat and were weighed separately. The procedure described by Akdag et al. (4) was utilized to determine the meat, bone, and fat weights in the total carcass. TCA = [(Cold Carcass Weight × AC_i) / Back Weight], where TCA is the total amount of meat, bone, or fat in the carcass and AC_i is the amount of cut section tissue (meat, bone, or fat) (4,14).

2.3. Chemical analyses

Samples were obtained of approximately 10–15 g from the *Musculus longissimus dorsi* of lamb carcasses. The meat samples were stored at –18 °C for later laboratory analyses. The chemical analyses of the dry matter, crude protein, ash, and ether extracted from the *Musculus longissimus dorsi* were performed according to Association of Official Agricultural Chemists standards (15). Dry matter content was determined by oven-drying for 24 h at 105 °C (Memmert UNE 400, Germany). Ether extract was calculated by measuring the weight of intramuscular fat that was extracted by diethyl ether using a Soxhlet extractor (BUCHI extraction system B-811, Switzerland). Crude protein (nitrogen × 6.25) was quantified by the Kjeldahl method (BuchiDigestion Unit K-424, Distillation Unit B-324, Switzerland), and the ashes were obtained through a muffle furnace at 550 °C (Carbolite ELF 11/14, UK).

2.4. Statistical analyses

The data, comprising the UST, UFT, ULD, ULW, and ULA measurements as observed from the 12–13T and 3–4L regions, were compared with paired sample t-test analysis. Descriptive statistics for the carcass traits and chemical compositions were calculated. In addition, correlations between UST, UFT, ULD, ULW, and ULA and among these, along with carcass traits and carcass chemical compositions, were determined using Pearson correlations. Multiple regression models and analyses were utilized to estimate the carcass traits and chemical compositions of the 12–13T and 3–4L regions. Model selections for multiple regressions were performed with a back-fitting methodology in additive regression models, as described by Jacoby (16). In the multiple regression models, the data (ultrasound measurements and live weight as the independent variables) observed from the 12–13T and 3–4L regions were fitted for dependent variables (carcass traits: warm carcass weight, cold carcass weight, dressing percentage, and carcass meat, fat, and bone amounts; carcass chemical composition: crude protein, fat, dry matter, and ash proportion). The best model was selected from the fitted models using the coefficient of determination (R^2) and the residual standard deviation (RSD) for evaluation (17), and this was also evaluated using the Durbin–Watson (DW) autocorrelation coefficient. The DW is a test statistic used to detect the presence or absence of an autocorrelation relationship between values separated from one another by a given time lag in certain residuals (also called prediction errors) from a regression analysis. It is calculated by the following equation described by Durbin and Watson (18) and also interpreted similarly:

$$DW = \frac{\sum_{t=2}^{T}(e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2}$$

Here, T is the number of observations, e is the error terms of t observations, and DW is a coefficient ranging from 0 to 4. The optimal DW coefficient was 2, since that would indicate no autocorrelation. A DW statistic of substantially less than 2 constitutes evidence of a positive serial correlation, while one of less than 1.0 may be cause for alarm. Small values indicating successive error terms are, on average, close in value to one another, or positively correlated. If DW > 2, successive error terms are, on average, much different in value from one another (i.e. negatively correlated). In regressions, this can imply an underestimation of the level of statistical significance.

3. Results

In this study, which was designed to determine the relationship between the ultrasound scanning of the 12–13T and 3–4L areas between the carcass traits and chemical composition, the comparison of readings from the two different anatomical regions is shown in Table 1. The differences of UST, UFT, ULD, ULW, and ULA values were determined to be statistically insignificant between the thoracic and lumbar measurements ($P > 0.05$).

The values of carcass traits and chemical composition of the carcass in Karayaka male lambs are given in Table 2. There was a variance of between 9.02% and 48.67% in carcass traits and 3.64% to 26.73% in chemical composition. Among all the attributes, the greatest variance (48.67%) was found to be in the carcass fat amount.

The phenotypic correlation coefficients of the 12–13T and 3–4L area measurements between the carcass traits and chemical composition are given in Table 3. The UST values gathered from the 12–13T area had a high negative correlation ($P < 0.05$) with warm carcass weight, cold carcass weight, and bone amount of the carcass. In addition, it was determined from the 12–13T measurements that there were positive correlations of UFT and ULW with live weight, warm carcass weight, cold carcass weight, carcass bone amount ($P < 0.01$), and meat amount ($P < 0.05$), while ULA only had a positive correlation with live weight ($P < 0.05$). The measurements from the 3–4L revealed a positive correlation of UFT with live weight, warm carcass weight, cold carcass weight, bone amount ($P < 0.01$), and meat amount ($P < 0.05$), and a high positive correlation of ULD only with carcass protein ratio ($P < 0.05$).

The regression equation of the ultrasound scanning from the two different regions to estimate carcass traits and chemical composition is given in Table 4. When the thoracic region ultrasound measurements were used to estimate carcass traits, adjusted R^2 values were found at

Table 1. Comparisons of ultrasound measurements taken from 12th–13th thoracic vertebrae and 3rd–4th lumbar vertebrae regions in male Karayaka lambs.

Traits	12th–13th thoracic vertebrae			3rd–4th lumbar vertebrae			P-value
	Mean	S.E.	CV (%)	Mean	S.E.	CV (%)	
UST (mm)	2.67	0.05	19.29	2.85	0.07	27.56	0.124
UFT (mm)	2.36	0.07	32.00	2.61	0.07	28.67	0.134
ULD (mm)	21.87	0.29	13.55	21.92	0.23	10.74	0.905
ULW (mm)	48.07	0.66	13.73	47.16	0.63	13.49	0.680
ULA (cm^2)	13.24	1.22	9.22	13.25	1.04	7.89	0.908

UST: Ultrasound skin thickness; UFT: ultrasound subcutaneous fat thickness; ULD: ultrasound muscle depth; ULW: ultrasound muscle width; ULA: ultrasound muscle area.

Table 2. Carcass traits and chemical composition of carcass in Karayaka lambs.

Traits	Mean	S.D.	CV (%)
Live weight (kg)	36.61	6.02	16.44
Carcass traits			
Warm carcass weight (kg)	16.61	3.14	18.93
Cold carcass weight (kg)	16.16	3.11	19.25
Dressing percentage (%)	44.13	3.98	9.02
Carcass meat (kg)	8.30	1.63	19.68
Carcass bone (kg)	4.09	0.79	19.52
Carcass fat (kg)	0.77	0.37	48.67
Chemical composition			
Crude protein (%)	19.63	1.40	7.13
Fat (%)	2.26	0.60	26.73
Dry matter (%)	25.84	0.94	3.64
Ash (%)	1.25	0.20	16.68

50%–94% while the lumbar readings' adjusted R^2 values were 49%–83% ($P < 0.05$).

4. Discussion

In male lambs, it was determined that the measurements of UST, UFT, ULD, ULW, and ULA at the 12–13T and 3–4L regions had similar values ($P > 0.05$). In some previous studies, ultrasound measurements from these two regions were found to be statistically insignificant (4,8,10). In this study, the UFT values from both regions were lower than those found by Sen et al. (19) in male Karayaka lambs of a similar age and weight; however, the ULA and ULD values were higher than in other study results (5,6,19). In some studies performed on different sheep breeds, the UFT, ULD, ULA (5,20), ULW, (12), and UST (21) values were higher than those found here. However, in other studies, the ULD (22,23), ULA (12), ULW (7), and UST (6,23) values were lower than those found here. The difference between this study and the others are thus concluded to be due to differences in breed, live weight, and feeding conditions, coupled with (ultrasound measuring) equipment and (equipment) user. Gökdal et al. (24) previously stated that the accuracy of ultrasound measurements is directly affected by the animal's age, sex, breed, and live weight, along with the ultrasound device used and the user's experience.

When the carcass traits and chemical compositions of male lambs were evaluated (Table 2), carcass fat amount was found to have the highest value for variation, with 48.67%. In addition, from the ultrasound measurements, UFT (Table 1) showed the greatest variation. According to this finding, the amount of fat tissue shows a relatively large range among individuals (25). In a study by Silva et al. (26) on two different sheep breeds, the fat amounts varied by 31%–38%, which was greater than the variations observed in relation to other traits. Emenheiser et al. (27) similarly reported that UFT and carcass fat amount variations were greater than those of other traits. In another study on sheep and male lambs, Silva et al. (20) reported that fat thickness, which had a variation of 62%, had the greatest variation value.

The phenotypic correlation coefficients among the ultrasound measurements and live weight carcass traits and carcass chemical composition of two different anatomical regions show that the live weight, warm and cold carcass weights, and meat and bone amounts in a carcass increase with an increase in UFT and ULW values (Table 3). From the measurements taken from the 3–4L region, only UFT had a high positive correlation with live weight, warm carcass weight, cold carcass weight, and the meat and bone amounts in the carcass, while other ultrasound measurement correlation coefficients were found to be insignificant. Supporting the current results, various authors have noted high positive correlations of UFT with live weight (7,22,23,28), cold carcass weight, bone amount (10), and meat amount (2,10). The fact that UFT measured from both regions in this study had a high correlation with live weight, warm carcass weight, cold carcass weight, and bone and meat amounts means that UFT may be used for a primary estimation of carcass traits (4,9). It was also reported by Agamy et al. that ULW values have a significant positive correlation with live weight (7);

Table 3. The phenotypic correlation coefficients between the ultrasound measurements and live weight (kg), carcass traits, and carcass chemical compositions.

Traits	UST	UFT	ULD	ULW	ULA
12th–13th thoracic vertebrae					
Live weight (kg)	–0.455	0.798**	–0.552	0.919**	0.595*
Warm carcass weight (kg)	–0.570*	0.862**	–0.498	0.935**	0.355
Cold carcass weight (kg)	–0.570*	0.864**	–0.485	0.933**	0.340
Dressing percentage (%)	–0.450	0.353	–0.004	0.296	–0.469
Carcass meat (kg)	–0.385	0.590*	–0.269	0.754**	0.271
Carcass bone (kg)	–0.664*	0.867**	–0.498	0.847**	0.276
Carcass fat (kg)	0.079	–0.394	0.230	0.036	0.015
Crude protein (%)	–0.391	–0.541	0.149	0.362	0.090
Fat (%)	0.167	0.442	0.434	–0.040	0.041
Dry matter (%)	–0.105	0.391	0.032	0.323	0.043
Ash (%)	–0.041	–0.318	0.237	–0.074	–0.233
3rd–4th lumbar vertebrae					
Live weight (kg)	–0.176	0.883**	0.097	0.284	0.239
Warm carcass weight (kg)	–0.319	0.756**	0.062	0.173	0.282
Cold carcass weight (kg)	–0.321	0.753**	0.070	0.156	0.282
Dressing percentage (%)	–0.382	–0.089	0.056	–0.126	0.273
Carcass meat (kg)	–0.017	0.560*	0.343	0.196	0.326
Carcass bone (kg)	–0.430	0.808**	0.148	0.113	0.220
Carcass fat (kg)	0.321	–0.289	0.503	0.306	0.464
Crude protein (%)	–0.108	0.841**	0.601*	0.090	0.267
Fat (%)	–0.012	–0.019	–0.436	–0.198	–0.237
Dry matter (%)	0.438	0.082	0.263	–0.073	–0.347
Ash (%)	–0.308	0.533	0.203	–0.264	–0.010

UST: Ultrasound skin thickness; UFT: ultrasound subcutaneous fat thickness; ULD: ultrasound muscle depth; ULW: ultrasound muscle width; ULA: ultrasound muscle area; *$P < 0.05$; **$P < 0.01$.

the same was reported for cold carcass weight by Ripol et al. (10). Kiyanzad (29) reported that ULW taken from the 12–13T region showed a high positive correlation with live weight, carcass meat amount, and bone amount in his study on Moghani and Makui sheep breeds. Ripol et al. (10) reported that from ultrasound measurements from four different anatomical locations, only the ULW taken from the 3–4L region had significant positive correlations with carcass meat, fat, and bone. In addition, while Cemal et al. (28) and Kiyanzad (29) found a high positive correlation between ULA and live weight, UST measurements from the 12–13T region showed a high negative correlation with warm carcass weight, cold carcass weight, and bone amount in the current study (Table 3). This result shows that an increase in UST value corresponds to lower warm and cold carcass weight and bone amounts. In this study, the negative relationship between UST and carcass traits could be due to lambs having poor body condition. It was reported that lambs with thick skin and lacking feed conversion have been determined to be in poor body condition (30). In contrast to the findings of this study, Ripol et al. (10) reported a positive correlation of UST with carcass bone, meat, and fat amounts.

UFT and ULD measurements taken from the 3–4L region have a high positive correlation with the carcass protein ratio in the present study (Table 3). These results indicate that there will be a high carcass protein ratio in lambs with high UFT and ULD values in the 3–4L region. Kiyanzad (29) also found a high positive correlation between UFT and carcass protein and carcass fat ratio in

Table 4. Multiple regression equations for ultrasound measurements and live weight for predicting carcass traits and chemical composition of the carcass in male Karayaka lambs.

Dependent variable	Independent variable										
	Constant	LW	UST	UFT	ULD	ULW	ULA	Adjusted R^2	RSD	DW	P
12th–13th thoracic vertebrae											
Warm carcass weight (kg)	1.680	0.369	9.440	–	–	2.807	–1.102	0.94	0.565	2.079	0.000
Cold carcass weight (kg)	1.546	0.356	10.553	–	–	2.972	–1.171	0.94	0.578	2.072	0.000
Dressing percent (%)	45.091	–0.337	6.331	–	4.249	8.874	–3.190	0.71	4.544	2.023	0.012
Carcass bone (kg)	0.662	0.056	–5.977	5.061	0.809	–	–	0.80	1.671	2.049	0.001
Carcass meat (kg)	1.111	0.184	12.626	–	–	1.577	–0.794	0.50	1.360	2.167	0.048
3rd–4th lumbar vertebrae											
Warm carcass weight (kg)	4.323	0.470	–6.655	–	–	–0.618	–	0.83	1.615	2.147	0.001
Cold carcass weight (kg)	4.466	0.463	–6.758	–	–	–0.687	–	0.81	1.757	2.148	0.001
Carcass bone (kg)	0.173	0.082	–3.601	1.594	0.698	–	–	0.65	0.230	1.855	0.020
Carcass meat (kg)	–7.420	0.213	–0.212	–	–	–0.298	0.694	0.49	1.491	2.184	0.050

UST: Ultrasound skin thickness; UFT: ultrasound subcutaneous fat thickness; ULD: ultrasound muscle depth; ULW: ultrasound muscle width; ULA: ultrasound muscle area; LW: live weight; RSD: residual standard deviation, DW: Durbin–Watson coefficient.

the Makui sheep breed. In a study performed on 6-month-old lambs, Ramsey et al. (31) found that ULD measured from the thoracic area had a positive correlation with carcass fat ratio and a negative correlation with carcass protein ratio.

When the regression equations used to estimate the carcass traits and chemical composition were examined (Table 4), it was shown that live weight in conjunction with the UST, ULW, and ULA measurements from the 12–13T region may be used to estimate warm and cold carcass weights with 94% accuracy. If the 3–4L measurements are to be utilized for the estimation of warm and cold carcass weights, the UST and ULW values should be used instead. For the estimation of the bone amount in the carcass, UST, UFT, and ULD values (from both regions) and live weight may be used; however, the 12–13T region measurements provide greater accuracy for estimation. For the carcass meat amount, the use of UST, ULW, ULA, and live weight in conjunction can offer 49%–50% accuracy. In addition, UST, ULD, ULW, and ULA measurements used with live weight provide a 71% likelihood of estimating dressing percentage. However, Orman et al. (12) could not develop a model to estimate dressing percentage from the USF, ULD, ULW, and ULA values taken from the 12–13T region in Ivesi lambs. They also reported that it was possible to estimate the carcass fat amount (R^2 = 75%–88%) and carcass weight (R^2 = 78%–90%) using UFT and ULA measurements and live weight. In their study on estimating carcass meat, bone, and fat amounts using UFT, ULA, ULD, and ULW measurements from 12–13T, Agamy et al. (7) reported that the carcass meat amount (R^2 = 82–85) could be estimated with live weight, ULW, and ULA values. They also reported that carcass fat amount could be determined with only the UFT measurement (R^2 = 69%–70%), and that the carcass bone amount might be estimated only with live weight (R^2 = 52%–81%). Silva et al. (20) remarked that muscle amount estimation (R^2 = 99%) may be made with live weight in conjunction with UFT and ULD values taken from the 12–13T region, and that live weight and UFT may be used to predict total fat amount (R^2 = 98%).

There is no statistically significant regression equation for predicting the chemical composition of the carcass from the USF, UFT, ULD, ULW, and ULA values taken from 12–13T and 3–4L in this study. Kiyanzad (29) could predict carcass meat, bone, and fat amounts with the regression analysis used to determine carcass traits and chemical composition; however, he could not determine regression equations important for the traits that constitute chemical composition. Finally, in a study performed on Churra da Terra Qente (CTQ) and Île de France breeds by Silva et al. (26), it was reported that ULD values may be used to determine the carcass protein amount for CTQ; in contrast, no ultrasound measurement could be used to estimate the protein ratio for Île de France.

From this study, it may be concluded that the chemical composition of the carcass cannot be determined by the ultrasound measurements taken from the 12–13T and 3–4L regions. However, ultrasonic measurements taken from 12–13T might be used for an accurate prediction of warm and cold carcass weights, dressing percentage, carcass meat, and carcass bone amounts (Table 4). In fact, when the regression equations for the two regions were evaluated, both the higher-adjusted 12–13T region R^2 values and the DW coefficients were at almost 2 (between 2.023 and 2.167), which supports this assumption (18). These results show that the ultrasound measurements taken from the 12–13T region, mainly UST, ULW, and ULA, combined with live weight, can be used to successfully estimate warm and cold carcass weights, dressing percentage, and carcass meat and bone amounts with very little deviation. This finding may be compared with those of Teixeira et al. (8) and Thériault et al. (9), who also reported that 12–13T measurements may be used to determine carcass traits. However, Ripol et al. (6) reported that 12–13T and 3–4L measurements had similar values and, for the prediction of carcass meat, bone, and fat amounts, the UFT, ULW, and ULD measurements should be used.

As a result, the ultrasound measurements from the 12–13T and 3–4L anatomical regions found in this study had similar values; it was determined that the ultrasound measurements and carcass traits were related. Furthermore, using live weight in combination with UST, ULW, and ULA from the 12–13T region made it possible to predict carcass traits. However, it is considered that new studies should be undertaken for the estimation of the chemical composition of the carcass, using regions other than 12–13T and 3–4L.

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