https://doi.org/10.22319/rmcp.v13i1.5986

Article

Correlation between *ante-mortem* and *post-mortem* variables in sheep carcasses produced in Mexico

Lizbeth Esmeralda Robles Jiménez [a]

José Armando Partida de la Peña [b]*

Miguel Enrique Arechavaleta Velasco [b]

Ignacio Arturo Domínguez Vara [a]

[a] Universidad Autónoma del Estado de México, Facultad de Medicina Veterinaria y Zootecnia, Estado de México, México.

[b] Instituto Nacional de investigaciones Forestales, Agrícolas y Pecuarias, Centro Nacional de Investigación Disciplinaria en Fisiología y Mejoramiento Animal, km 1 Carretera a Colón, Ajuchitlán, Querétaro, México.

*Corresponding author: partida.jose@inifap.gob.mx

Abstract:

The objective of the study was to estimate the correlations of the rib-eye area (REA) and the thickness of the dorsal subcutaneous fat (TDSF) with morphometric variables in sheep carcasses produced in Mexico. Seven hundred fifty sheep carcasses were used, which were grouped by genotype (hair, wool and crossed hair x wool), sex (males and females) and production system (intensive and semi-intensive). The normality of the distribution was determined, and simple correlation analyses were performed to estimate the degree of association between the variables. In hair genotypes, REA correlated with the weight of the carcass both hot and cold (r=0.42**; *n*=328; *P*<0.001 in males and r=0.48**; *n*=91; *P*<0.001 in females), but in females the perimeter (r=0.52**; *n*=91; *P*<0.001) and width of the rump (r=0.48**; *n*=91; *P*<0.001) were also relevant. In hair animals, the TDSF correlated with slaughter weight (r=0.36**; n=328; *P*<0.001 in males and r=0.57**; *n*=91; *P*<0.001 in females). In wool males, REA showed high correlation with carcass length (r=0.61**; *n*=116;

P<0.001) and rump perimeter (r=0.50**; *n*=116; *P*<0.001), while the TDSF correlated with the internal depth of the thorax (r=0.50**; *n*=116; *P*<0.01) and its perimeter (r=0.45**; *n*=116; *P*<0.001). In crosses hair x wool, REA had the highest correlation with thorax width (r=0.47**; *n*=215; *P*<0.001) and hot carcass weight (r=0.43**; *n*=215; *P*<0.001), while the TDSF only had a low correlation with slaughter weight (r=0.19**; *n*=215; *P*<0.001).

Key words: Sheep, Carcasses, Correlation, Rib-eye area, Fat thickness.

Received: 29/04/2021

Accepted: 16/08/2021

Introduction

In Mexico, sheep meat production has maintained an average annual growth of 4.7 % during the last twenty-five years, going from 29,887 t of carcass meat in 1995 to 64,758 t in 2020[1,2]. Currently, there is a population of almost 9.5 million heads and, based on the growth of the last five years, there is an expectation of producing 65,891 t of carcass meat by the end of 2021, with an estimated value of 6,500 million pesos[3]. Despite the good performance shown by the national sheep farming, Mexico does not have an official classification system for sheep carcasses and only has one standard (NMX-FF-106-SCFI-2006)[4] that is applied occasionally. There are also no quality standards that define the attributes of the sheep carcasses produced, nor are there differential prices based on the quality of the final product; there is only information that relates variables measurable *in vivo* with the properties of the carcass in the Pelibuey breed and in some of its crosses[5,6,7,8], as well as in crosses of Katahdin[9,10] and Hampshire[11] females with males of meat breeds.

Non-invasive methods for estimating the composition and quality of the carcass have been available in the world for some years[12], such as ultrasound, computed axial tomography, X-rays and positron emission tomography[13,14,15]; however, most of these methods are very expensive and impractical[16]. Some studies have also been carried out to determine the relationship that exists between some body components with the weight and yield of the carcass[17], as well as the relationship between body conformation and live weight using zoometric measures[18,19], but the results obtained are limited to very specific genetic groups and do not allow predicting aspects of quality in the carcass. For all the above, the objective of this study was to estimate the degree of association between *ante-mortem* and *post-mortem* variables with parameters indicative of quality, such as the rib-eye area and the thickness of the dorsal subcutaneous fat in sheep carcasses produced commercially in Mexico.

Material and methods

Seventy hundred fifty animals from the states of Mexico (60), Hidalgo (50), Veracruz (36), Zacatecas (38), Puebla (30), Jalisco (40), Coahuila (60), Sinaloa (187), San Luis Potosí (40), Guanajuato (30), Querétaro (64), Tabasco (35), Chiapas (45) and Yucatán (35) were evaluated, which were slaughtered in accordance with the NOM-ZOO-1995 Humanitarian Sacrifice of Domestic and Wild Animals[20]. The animals were finished in the intensive (fully stabled with balanced feed to freedom) and semi-intensive (grazing with strategic supplementation) production systems and slaughtered in the TIF or municipal slaughterhouse closest to the farms that allowed to access to their facilities and provided to this search with information prior to the slaughter. It was identified 11 pure breeds, of which the following stood out: Katahdin 11.0 %, Pelibuey 5.1 %, Rambouillet 5.0 %, Suffolk 3.4 %, Dorper 2.8 % and more than ten crosses, of which the most representative were: Pelibuey x Katahdin 16.3 %, Pelibuey x Dorper 9.6 %, Katahdin x Suffolk 9.0 %, Katahdin x Charollais 5.8 %, Katahdin x Dorper 5.4 %.

For the analysis of the data, the sex, breed and production system of each of the animals were identified. Using the methodology described by Partida *et al*[21], records were taken of the slaughter weight, weight of the hot and cold carcass, yield of the hot and cold carcass, internal length of the leg (most caudal distance of the perineum and the most distal point of the medial edge of the tarsometatarsal articular surface), carcass length (maximum distance between the anterior edge of the ischiopubic symphysis and the anterior edge of the first rib, at its midpoint), rump perimeter (at the level of the trochanters of both femurs), rump width (maximum width between the trochanters of both femurs), thorax width (maximum width between the ribs at the level of the 6th thoracic vertebra), thoracic perimeter (circumference of the carcass over the ribs at the height of the 6th thoracic vertebra) and internal depth of the thorax (maximum distance between the sternum and the back of the carcass at the level of the 6th thoracic vertebra) of each of the animals. Likewise, the carcass compactness index (weight of the cold carcass in kg / internal length of the carcass in cm) was calculated, the rib-eye area (in the cutting area at the level of the 13th rib) and the thickness of the dorsal subcutaneous fat (also in the cutting area over the 13th rib) were measured, variables that are related to carcass quality[22].

All animals were classified according to their genetic group (hair, wool and crossed hair x wool), sex (males and females) and production system (intensive and semi-intensive). From this classification, the following four groups of animals were formed: hair males produced under the semi-intensive system (*n*= 328), hair females produced under the semi-intensive system (*n*= 91), wool males produced under the intensive system (*n*= 116) and crossed males produced under the semi-intensive system (*n*= 215).

Initially, analyses were performed within each group to determine if the distribution of the variables included in the study followed a normal distribution, for this the Kolmogorov-Smirnov and Shapiro-Wilk tests were used[23], and subsequently simple linear correlation analyses were performed to estimate the degree of association between *in vivo* and *post-mortem* variables with the rib-eye area and the thickness of the dorsal subcutaneous fat. Statistical analyses were performed using the JMP statistical package ver. 4.0[24].

Results and discussion

The Kolmogorov-Smirnov and Shapiro-Wilk analyses showed that the distribution of the variables included in the study followed a normal distribution.

In the group of hair males produced under the semi-intensive system, a positive and highly significant correlation was obtained between the rib-eye area (REA) and slaughter weight (r= 0.38**; *n*= 328; P<0.001), the hot carcass weight (r= 0.42**; *n*= 328; P<0.001) and cold carcass weight (r= 0.42**; *n*= 28; P<0.001), with averages of 43.34 ± 6.22; 21.46 ± 3.15 and 20.90 ± 3.04 kg respectively for the variables mentioned. In this group, the thickness of the dorsal subcutaneous fat (TDSF) was also positively and highly significantly correlated with slaughter weight (r= 0.36**; *n*= 328; P<0.001) and with the internal depth of the thorax (r= 0.34**; *n*= 91; P<0.001) (Table 1).

Table 1: Correlation of rib-eye area and thickness of the subcutaneous fat with different carcass variables in hair males of the semi-intensive system (n= 328)

Variables	SW	HCW	CCW	HCY	CCY	RP	RW	IDT	CCI
REA	0.38**	0.42**	0.42**	0.15**	0.16	0.27**	0.28**	0.15**	0.24**
TDSF	0.36**	0.23**	0.26**	-8.08	-0.11	0.25**	0.20**	0.34**	0.17**

SW= slaughter weight; HCW= hot carcass weight; CCW= cold carcass weight; HCY= hot carcass yield; CCY= cold carcass yield; RP= rump perimeter; RW= rump width; IDT= internal depth of the thorax; CCI= carcass compactness index. REA= rib-eye area; TDSF= thickness of the dorsal subcutaneous fat.

In the group of hair females produced under the semi-intensive system, REA showed highly significant coefficients of determination with hot carcass weight (r= 0.48**; *n*= 91; *P*<0.001) and cold carcass weight (r= 0.49**; *n*= 91; *P*<0.001), as well as with rump perimeter (r= 0.52**; *n*= 91; *P*<0.001), rump width (r= 0.48**; *n*= 91; *P*<0.001) and the carcass compactness index (r= 0.43**; *n*= 91; *P*<0.001). For its part, the TDSF showed the highest coefficient of determination with slaughter weight (r= 0.57**; *n*= 91; *P*<0.001) (Table 2).

Table 2: Correlation of rib-eye area and thickness of the subcutaneous fat with different carcass variables in hair females of the semi-intensive system (n= 91)

Variables	SW	HCW	CCW	HCY	CCY	RP	RW	IDT	CCI
REA	0.32*	0.48**	0.49**	0.34*	0.36**	0.52**	0.48**	0.34*	0.43**
TDSF	0.57**	0.03	0.02	0.36**	0.34**	0.31*	0.09	-0.11	-0.05

SW= slaughter weight; HCW= hot carcass weight; CCW= cold carcass weight; HCY= hot carcass yield; CCY= cold carcass yield; RP= rump perimeter; RW= rump width; IDT= internal depth of the thorax; CCI= carcass compactness index. REA= rib-eye area; TDSF= thickness of the dorsal subcutaneous fat.

The relationship between REA and the weight of the carcass, both hot and cold, which was observed in hair males and females produced under the semi-intensive system is consistent with what has been reported in the literature for some time(25,26,27), and is explained by the analogy between body size and the dimensions of each of the components that make up the carcass (allometric growth). However, some authors have indicated that live weight may present certain deficiencies as an indicator of body composition, because the distinction between different stages of maturity of the animal cannot be made(28). In this study, there was evidently variation in the age of the animals and in their degree of maturity, but this information was not provided by the producers before or at the time of slaughter.

It is known that REA is a good estimator of the proportion of muscle existing in the carcass of different domestic species(29,30); in fact, very high correlations (r= 0.96) have been obtained between cold carcass weight and its proportion of muscle when extremely homogeneous genetic groups have been evaluated, such as, for example, lactating lambs of the Manchega breed, which were handled and fed under the same conditions(31). This shows that carcass weight could be useful and practical for estimating the REA and the proportion of muscle in the carcass, since its weighing is an easy and quick measurement. According to the results, the variable that had the highest correlation with TDSF was slaughter weight, both in hair females and males. This has also been observed in some studies that used ultrasound to measure fat cover in the sheep carcass(32,33,34). Similarly, in sheep of the Texel breed (with 20 kg of live weight), a correlation (r= 0.33; 186 *P*<0.05) was reported between slaughter weight and the TDSF(35). Likewise, other authors who used lambs of the Awassi breed observed a correlation between the TDSF and slaughter weight, which increased (r= 0.71 to r= 0.83) when the body weight increased from 30 to 40 kg and when differentiating the sex within the model(34).

As for the group of wool males raised in the intensive system, REA had a positive correlation with carcass length (r= 0.61**; *n*= 116; *P*<0.001) and rump perimeter (r= 0.58**; *n*= 116; *P*<0.001), while in dorsal TDSF, it was positively correlated with hot carcass yield (r= 0.42**; *n*= 116; *P*<0.001), the perimeter of the thorax (r= 0.45**; *n*= 116; *P*<0.001) and its internal depth (r= 0.50**; *n*= 116; *P*<0.001) (Table 3).

Table 3: Correlation of rib-eye area and thickness of the subcutaneous fat with different carcass variables in wool male sheep of the intensive system (n= 116)

Variables	HCY	CCY	RP	TP	LL	CL	IDT	CCI
REA	-0.14	-0.01	0.58**	-0.08	-0.07	0.61**	-0.1	-0.20*
TDSF	0.42**	0.29**	-0.25*	0.45**	0.33**	-0.25*	0.50**	0.30**

HCY= hot carcass yield; CCY= cold carcass yield; RP= rump perimeter; TP= thorax perimeter; LL= leg length; CL= carcass length; IDT= internal depth of the thorax; CCI= carcass compactness index. REA= rib-eye area; TDSF= thickness of the dorsal subcutaneous fat.

The high correlations of REA with carcass length have also been reported by other authors(31) who used lactating sheep of the Manchega and Churra Tensina breeds to predict the composition of the carcass, and observed that its length was the best correlated variable (r= 0.869 and r= 0.31, respectively for each of the breeds) with the weight of the muscle and concluded that the carcass length has a positive correlation with all usable meat, because longer carcasses have longer hindquarters, which have an important contribution to meat yield. This indicates that the greater the length and width of the carcass, the greater the amount of meat could be obtained from it, since the rib-eye area has shown a close correlation with the total amount of muscle present in the carcass(36); even in Australia, sheep farmers select the longest sheep because they assure that they are the ones that will produce the greatest amount of meat(37).

When examining the variables that had a correlation with the thickness of the subcutaneous fat in wool sheep, it was observed that the thoracic perimeter and the internal depth of the thorax were the variables that showed the best correlation (r= 0.45; *n*= 116; *P*>0.001 and r= 0.50; *n*= 116; *P*>0.001, respectively), which is consistent with the results of other authors(16) who, when characterizing a new wool breed, indicated that the rib is the cut best correlated with the amount of subcutaneous fat in lambs, since the rib was the region of the carcass with the highest deposit of adipose tissue(38). However, other authors who evaluated sheep of the Manchega breed determined that there is also a high correlation (r= 0.70) between thorax width and the amount of muscle existing in the carcass[31].

In the group of crossed males produced in the semi-intensive system, the highest correlations of REA with thorax width (r= 0.47**; *n*= 215; *P*<0.001) and hot carcass weight (0.43**; *n*= 215; *P*<0.001) were obtained, while the TDSF only showed a low correlation with slaughter weight (r= 0.19**; *n*= 215; *P*<0.001) (Table 4).

Table 4: Correlation of rib-eye area and thickness of the subcutaneous fat with different carcass variables in crossed (hair x wool) male sheep of the semi-intensive system (n=215)

Variables	Slaughter weight	Hot carcass weight	Cold carcass weight	Thorax width	Leg length
REA	0.37**	0.43**	0.39**	0.47**	0.40**
TDSF	0.19**	0.14	0.12	0.06	-0.05

REA= rib-eye area; TDSF= thickness of the dorsal subcutaneous fat.

Also in the crossed (hair x wool) males, the relationship between REA and carcass weight was maintained, which coincides with what was observed in the other two groups of the semi-intensive system, which may be due to the greater participation of hair breeds such as Pelibuey and Katahdin in this type of productive system[21]. For its part, the correlation of REA with thorax width could be more associated with the participation of meat breeds such as Dorper, which is characterized by its dimensions of perimeter and width of the thorax, derived from the genetic improvement that has focused on the selection of animals with a wider trunk. Currently, producers seek animals with greater trunk thickness, because they are the ones with the greatest amount of muscle in the carcass[37].

In general, and despite the strong variation in the sheep carcasses produced in the country, carcass weight could be a useful and practical variable to estimate the proportion of muscle that makes it up; additionally, the weighing of the carcass is an easy, fast and economical measurement. Notwithstanding the foregoing, it is convenient to obtain prediction equations for each of the autochthonous genotypes, so as to minimize the errors involved in the application of equations that were calculated for other genotypes and weight ranges[39].

Conclusions and implications

Under the conditions in which the present study was carried out and despite the high heterogeneity that exists in the sheep carcasses produced in Mexico, it was observed that in hair males and females of the semi-intensive system, as well as in the hair-by-wool crosses of that same system, the weight of the carcass, both hot and cold, correlated with the rib-eye area, which is a good estimator of the proportion of muscle in the carcass. Likewise, in hair males and females of the semi-intensive system, slaughter weight correlated with the thickness of the dorsal subcutaneous fat, which indicates the degree of finishing of the animal. On the contrary, in wool males of the intensive system, measurements of carcass length and rump perimeter had the best correlations with the rib-eye area, which is known to be a true estimator of carcass muscle. In general, it can be concluded that the best correlations between the parameters studied are associated with the body characteristics of the animal and with the particularities of the carcass, which are caused by the genotype of the animal. This implies that measurements on the live animal or its carcass could be very useful for producers and processors to have a better idea of the quality of the meat they offer to the market.

Acknowledgements

The authors thank CONACYT for the funding of this work and for the scholarship for studying a master's degree in science for the first author.

Conflict of interest

The authors of this paper declare that there is no conflict of interest of any kind.

Literature cited:

1. SIACOM. Servicio de Información Agroalomentaria de Consulta. https://nube.siap.gob.mx/index.php/s/AQROGZKKqEek6wh. Consultado 22 Abr, 2021.

2. SIAP. Sistema de Información Agroalimentaria y Pesquera. Resumen Nacional Producción, Precio, Valor, Animales sacrificados y Peso. http://infosiap.siap.gob.mx/anpecuario_siapx_gobmx/ResumenNacional.do;jsessionid=169DC54CFE6DCBA023DC67653184405E. Consultado 22 Abr, 2021.

3. SNIIM. Sistema Nacional de Información e Integración de Mercados. SNIIM - Sistema Nacional de Información de Mercados. Secretaría de Economía Precios de Frutas, Hortalizas, Vegetales, Carnes, Pescados, Pecuarios, Pesqueros (economia-sniim.gob.mx). Consultado 22 Abr, 2021.

4. NMX-FF-106 SCFI-2006. Norma Mexicana para la Clasificación de Carne Ovina en Canal. Productos Pecuarios. Publicada en el Diario Oficial de la Federación el 21 de agosto de 2006.

5. Gutiérrez J, Rubio MS, Méndez RD. Effects of crossbreeding Mexican Pelibuey sheep with Rambouillet and Suffolk on carcass traits. Meat Sci 2005;70:1-5. doi.org/10.1016/i.meatsc.2004.10.017.

6. Bautista-Diaz E, Salazar-Cuytun R, Chay-Canul A, García-Herrera R, Piñero-Vázquez A, Magaña-Monforte J, *et al*. Determination of carcass traits in Pelibuey ewes using biometric measurements. Small Ruminant Res 2017;147:115-119. doi.org/10.1016/j.smallrumres.2016.12.037.

7. Partida PJA, Braña BD, Martínez RL. Desempeño productivo y propiedades de la canal en ovinos Pelibuey y sus cruzas con Suffolk o Dorset. Téc Pecu Méx 2009;47(3):313-322.

8. Aguilar-Hernández E, Chay-Canul A, Gómez-Vázquez A, Magaña-Monforte J, Ríos-Rincón F, Cruz-Hernández A. Relationship of ultrasound measurements and carcass traits in Pelibuey ewes. J Anim Plant Sci 2016;26(2):325-330.

9. Vázquez SET, Partida PJA, Rubio LMS, Méndez MD. Comportamiento productivo y características de la canal en corderos provenientes de la cruza de ovejas Katahdin con machos de cuatro razas cárnicas especializadas. Rev Mex Cienc Pecu, 2009;2(3):247-258.

10. Partida PJA, Vázquez E, Rubio MS. Méndez MD. Effect of breed sire on carcass traits and meat quality of Katahdin lambs. J Food Res 2012;1(4):141-149.

11. López VMM, De la Cruz CL, Partida PJA, Torre HG, Becerril PC, Buendía RG, Jiménez BMR, Alfar RRH. Efecto de la raza paterna en las características de la canal de corderos en un sistema de producción comercial en Hidalgo, México. Rev Mex Cienc Pecu 2016;7(4):441-453.

12. Scholz AM, Bünger L, Kongsro J, Baulain U, Mitchell AD. Non-invasive methods for the determination of body and carcass composition in livestock: dual-energy X-ray absorptiometry, computed tomography, magnetic resonance imaging, and ultrasound: invited review. Animal 2015;9:1250-1264.

13. Lambe N, Navajas E, BüngerL, Fisher A, Roehe R, Simm G. Prediction of lamb carcass composition and meat quality using combinations of *post-mortem* measurements. Meat Sci 2009;81:711-719. doi:10.1016/j.meatsci.2008.10.025.

14. Navajas EA, Glasbey CA, Mclean KA, Fisher AV, Charteris AJL, Lambe, NR, Bünger L, Simm G. “Science: *In vivo* Measurements of muscle volume by automatic image analysis of spiral computed tomography scans. Anim Sci 2006;82(4):545-553. doi:10.1079/ASC200662.

15 . Ripoll G, Joy M, Alvarez-Rodríguez J, Sanz A, Teixeira A. Estimation of light lamb carcass composition by *in vivo* real-time ultrasonography at four anatomical locations 1. J Anim Sci 2009;87(4):1455-1463. doi: 10.2527/jas.2008-1285.

16. Camacho A, Perez V, Mata J, Bermejo LA. Ecuaciones predictoras de la composición tisular de la canal en dos razas ovinas canarias. Arch de Zootec 2011;60:1125-1135.

17. González GR, Salinas HRM, Garduza AG, Reyes MF. Componentes corporales en ovinos de pelo para abasto en el sureste mexicano. Zootec Trop 2014;32(1):23-32.

18. Vilaboa AJ, Bozzi R, Díaz RP, Bazzi L. Conformación corporal de las razas ovinas Pelibuey, Dorper y Katahdin en el estado de Veracruz, México. Zootec Trop 2010;28(3)321-328.

19. Pulgarón BPP, Castro AR, Yglesias RO. Relación entre el peso y las medidas corporales al nacimiento en hembras y machos ovinos de la raza Pelibuey. Engormix ovinos 2012. https://www.engormix.com/ovinos/foros/relacion-entre-peso-medidas-t14793/. Consultado 28 Abr, 2021.

20. NOM-033-ZOO-1995: Sacrificio Humanitario de los Animales Domésticos y Silvestres. Secretaría de Agricultura, Ganadería y Desarrollo Rural. Publicada en el Diario Oficial de la Federación el 16 de julio de 1995.

21. Partida PJA, Ríos RFG, De la Cruz CL, Domínguez VIA, Buendía RG. Caracterización de las canales ovinas producidas en México. Rev Mex Cienc Pecu 2017;8(3):269-277. http://dx.doi.org/10.22319/rmcp.v8.

22. Cañeque V, Sañudo AC. Estandarización de las metodologías para la evaluar la calidad del producto (animal vivo, canal, carne y grasa) en los rumiantes. Monografías INIA: Serie Ganadera No. 3 Madrid, España. 2005.

23. Field A. Regression. Discovering Statistics Using SPSS. 3º ed. SAGA. 2009.

24. SAS. JMP. (Statistical Discovery Software), Ver 4.0 (academy); Cary N. C. USA Inst. Inc. 2002.

25. Delfa R, González C, Teixeira A. Use of cold carcass weight and fat depth measurements to predict carcass composition of raza Aragonesa. Small Ruminant Res 1996;20:267-274.

26. Safari E, Hopkins DL, Fogarty NM. Diverse lamb genotypes 4. Predicting the yield of saleable meat and high value trimmed cuts from carcass measurements. Meat Sci 2001;58:207-214.

27. Carrasco S, Ripoll G, Panea B, Álvarez-Rodríguez J, Joy M. Carcass tissue composition in light lambs: Influence of feeding system and prediction equations. Livest Sci 2009; 126:112-121. doi:http://dx.doi.org/10.1016/j.livsci.2009.06.006.

28. Cavanauh CR, Jonas E, Hobbs M, Thomson PC, Tamman I, Raadsma HW. Mapping Quantitative Trait Loci (QTL) in sheep. III. QTL for carcass composition traits derived from CT scan and aligned with a meta-assembly for sheep and cattle carcass QTL. Genet Select Evol 2010;42:36.

29. Silva SR, Gudes CM, Santos VA, Lourenco Al, Azevedo JM, Dias-da Silva A. Sheep carcass composition estimated from *Longissimus thoracis et lumborum* muscle volume measured by *in vivo* real-time ultrasonography. Meat Sci 2007;76(4):708-714. doi: 10.1016/j.meatsci.2007.02.009.

30. Morais MG, Biava MB, Bertholini RC, Walker CC, Fernandes HJ, Duarte LSAR, Brandão FÍCC, Dias FGL. Models predict the proportion of bone, muscle, and fat in ewe lamb carcasses from in vivo measurements of the 9th to 11th rib section and of the 12th rib. Semina: Ciências Agrárias 2016;37(2):1081-1090. doi:10.5433/1679-0359.2016v37n2p1081.

31. Díaz MT, Cañeque V, Lauzurica S, Velasco S, Ruiz de Huidobro F, Perez C. Prediction of suckling lamb carcass composition from objective and subjective carcass measurements. Meat Sci 2004;66:895-902. doi.10.1016/j.meatsci.2003.08.013.

32. Leeds TD, Mousel MR, Notter DR, Zerby HN, Moffet CA, Lewis GS. B-mode real-time ultrasound for estimating carcass measures in live sheep: Accuracy of ultrasound measures and their relationships with carcass yield and value. J Anim Sci 2008;86:3203-3214. doi: 10.2527/jas.2007-0836.

33. Orman A, Calışkan UG, Dikmen S, Ustuner H, Oğan M, Calışkan C. The assessment of carcass composition of Awassi male lambs by real-time ultrasound at two different live weights. Meat Sci, 2008;80:1031-1036. doi:10.1016/j.meatsci.2008.04.022.

34. Orman A, Caliskan GU, Dikmen S. The assessment of carcass traits of Awassi lambs by real-time ultrasound at different body weights and sexes. J Anim Sci 2010;88(10):3428-3438. doi:10.2527/jas.2009-2431.

35. Wolf BT, Jones DA, Owen MG. *In vivo* prediction of carcass composition and muscularity in purebred Texel lambs. Meat Sci 2006;74(2):416-423. doi:10.1016/j.meatsci.2006.02.019.

36. Williams AR. Ultrasound applications in beef cattle carcass research and management. J Anim Sci 2002;80:183-188. doi:10.2527/animalsci2002.80E-Suppl_2E183x.

37. Anderson F, Pannier L, Pethick DW, Gardner GE. Intramuscular fat in lamb muscle and the impact of selection for improved carcass lean meat yield. Animal. 2015.1081-1090. doi: 10.1017/S1751731114002900.

38. Yakan A, Ünal N. Meat production traits of a new sheep breed called Bafra in Turkey 1. Fattening, slaughter, and carcass characteristics of lambs. Trop Anim Health and Produc 2010;42(4):751-759. doi 10.1007/s11250-009-9483-8.

39. Lauz FOG, Diniz RF, Teixeira CRA. Francieli FV, Benetti M. Measurement of rib-eye area by the method of digital images. R Bras Zootec 2012;4(3). doi.http://dx.doi.org/10.1590/51516-35982012000300047.