Scientific Papers. Series D. Animal Science. Vol. LXIV, No. 1, 2021
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

ULTRASOUND MEASUREMENTS OF EYE MUSCLE PROPERTIES AND BACKFAT THICKNESS IN LAMBS FROM DIFFERENT GENOTYPES FED WITH DIFFERENT DIETS

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Abstract

The present study was conducted to determine eye muscle (M. Longissimus dorsi) properties of lambs from two genotypes. The depth, eye muscle area and eye muscle perimeter of Longissimus dorsi and thickness of fat covering this muscle using ultrasonic scan was determined using ultrasonic measurements from 118 lambs taken from the two different genotypes - 80 heads from Tsigai - rusty variety (40 female and 40 male) and 38 heads (30 female and 8 male) from Suffolk (50%) x German Blackface (37.5%) x Tsigai (12.5%).The animals were fed with different diets. Birth weight was significantly (p<0.05) affected by breed and sex. Likewise, weaning weight and weight at 5 months was found to be significantly affected by sex and breed. Mean for ultrasound measurements of eye muscle properties were highly significant (p<0.001; p<0.01) for eye muscle depth at 12 rib, eye muscle area at 12 rib and 3-4 lumbar vertebrae, and for backfat thickness in the two points; significant differences (p<0.05) were found for eye muscle depth and area at 3-4 lumbar vertebra, but no significant differences were found for eye muscle perimeter (p>0.05). The lamb sex and breed was found to be significant variable for eye muscle area and the lamb diet for eye depth at 3-4 lumbar vertebrae. Regarding the phenotypic correlations between ultrasound measurements with weight at 5 months, from a total of 45 traits couples, 46.66% are small correlation (0.00-0.30), 26.67% are medium to high correlations (0.31-0.60) and high correlations recorded 26.67% (0.61-1.00). Due to the lack of labor in agriculture, in the last years many sheep breeders do not want to milk the sheep, they prefer to let the lambs graze along with their mothers, so that the lambs are marketed at the age of 4-5 months. It is extremely difficult to take measurements on carcasses in these regions as lambs are mainly marketed or slaughtered as small groups or individually and abattoirs do not record any measurements on carcasses characteristics. In this situation, information on body composition of lambs can be obtained practically by ultrasonic measurements on live animals. When combined in a breeding program with lamb weight at 5 months or market weights, these measurements will provide a way to increase both meat yield and the quality of lambs.

Key words: *genotype, lamb, Longissimus dorsi, Tsigai, ultrasound.*

INTRODUCTION

Real-time ultrasonography is a non-invasive technology that allows carcass quality to be assessed without damaging the product (Delfa et al., 1996; Fernández et al., 1998; Mendizabal et al., 2003). The relatively low cost and ease of portability of ultrasound equipment has led ultrasound measurements to be incorporated into national genetic programs for lamb carcass quality improvement in many parts of the world (Stanford et al., 1998).
The ultrasound measurement is a new technique which is a non-invasive, efficient grading method for classification and quantification of the animal carcasses in their early life as well as the further usage of animals for reproduction. The measured parameters (subcutaneous fat layer thickness, muscle eye area and muscle depth) add new selection indices (muscle depth and subcutaneous fat layer thickness) to the classical ones (body weight, carcass meat). The ultrasound method is mostly used for sheep carcass grading in the western EU countries which have a long tradition in sheep rearing and breeding for meat production. Applications of this modern technology are already deployed in the UK,

New Zealand and Ireland for the breeding programmes (Fogarty et al., 1992, 1995; Wilson, 1992; Russel, 1995; Larsgard & Kolstad, 2003), showing very good correlations with the classical method. Fernández et al. (1997) stated close correlations between the ultrasound measurements and the carcass measurements of LD muscle for muscle eye area, muscle depth and thickness of the subcutaneous fat layer (0.88, 0.74 and 0.56, respectively) in Manchego lambs. Moderate correlations between the ultrasound measurements and the carcass assessment for muscle eye area and weaning body weight, and between the thickness of the subcutaneous fat layer and weaning body weight were determined by Fernández et al. (1998) and Ibrahim et al. (2007). Emenheiser et al. (2010) showed the necessity of validating the ultrasound method utilization to determine lamb carcass composition for meat production and showed the advantages of this method. Therefore, ultrasound can offer breeders, producers and researchers the ability to estimate carcass composition traits in vivo and thus contribute knowledge to precision of breeding, management and marketing decisions (Leeds et al., 2008).
The study was conducted to determine backfat thickness and Longissimus dorsi muscle properties of lambs from Tsigai breed and crossbred Suffolk (50%) x German Blackface (37.5%) x Tsigai (12.5%) lambs using ultrasonic measurements and to evaluate the effects of diet, genotype, and sex on these parameters. By providing the first reference for these phenotypic parameters with ultrasonic measurements, this study may assist with the initiation of a genetic breeding program which includes ultrasonic measurements to improve meat yield and in turn the quality of lambs from Tsigai - rusty variety.

MATERIALS AND METHODS

The present research was conducted in Experimental Base Reghin of Research Institute for Sheep and Goat Palas Constanta, Mures County, 46°46' N/ 22°42'E; 395 m altitude; annual rain fall varies between 650-700 mm; average temperatures 19/–3°C during summer/winter).

Animal management

118 lambs (one hundred and eighteen) separated into five lots, from Tsigai - rusty variety (80 heads, from which: 40 males - lot 1 (L1) and 2 (L2) - 20 heads/lot; 40 females - lot 3 (L3) and crossbred lambs Suffolk (50%) x German Blackface x Tsigai (SxBFxTi) - 30 female - lot 4 (L4) and 8 males - lot 5 (L5) was used as animal material in this study. The sheep mothers were raised in extensive conditions, were kept on pastures throughout the year. However, concentrate are used in feeding of ewes as supplement during some critical periods, such as late gestation and 2 month after lambing. Lambs were born from January through March. At birth or shortly thereafter, lambs were identified with ear tags and weighed (± 0.1 kg). Sex, date of birth, type of birth, dam and ram group were recorded. The lambs were also weighed monthly (± 0.1 kg) up to 5 months age. Ewes and their lambs were kept together under the same management condition for two months after lambing. Lambs were weaned at approximately 58-62 days to Tsigai breed and 57-62 days of age to crossbred lambs. In the suckling period, the diet was formulated for 300 g/head/day growth potential according to NRC (1985) requirements (135 g DP and 10.89 MJ NE).
The structure of concentrated fodder was: 30% corn flour, 30% barley flour, 25% corn grain, 11.25%, sunflower groats, 2.25% calcium and 1.5% salt. After weaning up to 5 months, the five lots of lambs were fed with different diet, the lambs were raised on shelter, and the diet was offered *ad libitum.* For the lot 1, the structure of concentrate fodder was the same like in the suckling period (from birth up to end of fattening), for the lot 2 it was different in comparison to suckling period and separated into two phases during the fattening period, and for the lots 3, 4, and 5 the diet was without differences between the 3 lots during the fattening period. The structure of concentrate fodder is presented in Table 1. Additional, for all lots, in the ration was added hill hay.
The lambs were measured for birth weight (BW), weaning weight (WW), and weight at 5 months (W5M), musculus Longissimus dorsi (LD) depth (LMD), area (LMA) and perimeter (LMP) and backfat thickness (BF) covering this muscle at the area between the 12th and 13th

rib, and between 3 and 4 lumbar vertebrae using ultrasonic scan.

Table 1. Structure of concentrate fodder used in fattening experiment with lambs from different genotyp

Characteristics	After weaning					
	L1	L2		L3	L4	L5
	6 April 15 July	6 April 6 Juni	7 Juni 15 July	6 April 15 July	6 April 15 July	6 April 15 July
Corn flour (%)	30.0	4.00	20.0	4.00	4.00	4.00
Characteristics	After weaning					
	L1	L2		L3	L4	L5
	6 April 15 July	6 April 6 Juni	7 Juni 15 July	6 April 15 July	6 April 15 July	6 April 15 July
Barley flour (%)	30.0	4.00	20.0	4.00	4.00	4.00
Corn grain (%)	25.0	90.00	50.0	90.00	90.00	90.00
Sunflower groats (%)	11.25	1.50	7.5	1.50	1.50	1.50
Calcium (%)	2.25	0.30	1.5	0.30	0.30	0.30
Salt (%)	1.5	0.2	1.0	0.2	0.2	0.2
Dry matter/ kg concentra ted fodder	820	830	830	830	830	830
Digestible protein g/kg dry matter	135	100	118	100	100	100
NE MJ/kg dry matter	10.89	11.29	10.89	11.29	11.29	11.29

Wool was removed from measurement areas by shearing before ultrasonic scanning. The ultrasonic measurements were performed by an experienced operator *in vivo* using a HS-1600 (HONDA ELECTRONICS CO.) ultrasonic machine with a HLV 7218 linear probe and the following operating frequencies: 1.5/2.0/3.0 Mhz.

All recorded images were then analysed with ImagesJ program.

After scan image capture, the muscle depth, Longissimus dorsi area and perimeter, and the thickness of backfat at the two points was measured using the electronic calliper of the scanner. The resolution of scanner calliper was 0.01 cm. Longissimus dorsi area and perimeter was measured on the same image after the borders of muscle had been drawn.

Statistical data processing was performed with the ANOVA program, and the tests used were the "Tukey" tests.

RESULTS

The body evolution, total gain and average daily gain (ADG) from birth to end of fattening are presented in Table 2.

The minimum average live weight of lambs at birth was comprised between 4.22 kg at L3 (female from Tsigai breed) and 4.95 kg at L5 (male from crossbred lambs). Significant differences ($p<0.05$) were recorded between L3 and the lots L4 and L5 with regard at birth weight. The analyses have indicated significant effects on weight at 5 months of breed and sex. Male weights of female lambs in L4 were found 7.12 kg heavier than female lambs in L3. Also, the weight at 5 months of female from L4 were found 1.65 kg heavier than male lambs in L2. Male lambs in L5 were found to be significantly heavier than the females from the same genotype (48.57 vs. 41.83 kg; $p<0.01$). At the same time, significant differences were found between the lots of lambs from the two genotypes, so, between L5 and L1 ($p<0.05$) and between L5 and L2 ($p<0.001$). Significant differences ($p<0.001$) were found between all lots of lambs and lambs of female from Tsigai sheep (L3). No significant differences were found between the lots of male lambs from Tsigai sheep, therefore the weight at 5 months was not influenced by the diet.

The statistics for ultrasonic measurements of the eye muscle properties and lambs weights of lambs at 5 month are given in Table 3. The difference observed due to the sex of lambs was significant for backfat thickness ($p<0.05$), muscle depth ($p<0.01$) and eye muscle area ($p<0.001$). Between the means of lots were highly significant differences ($p<0.001$) for eye muscle area at the lots L2 (male) and L4 (female), and significant ($p<0.01$) for the lots of female (L3, L4), compared to the lots L1 and L2. The eye muscle area was higher to female lambs from the two genotypes, compared to male lambs from Tsigai breed (1.59 cm^2 higher L4 compared to L1 and 1.97 cm^2 L4 vs. L2, respectively; likewise, 1.08 cm^2 higher to L3 compared to L1 and 1.46 cm^2 higher L3 compared to L2, respectively). The difference observed due to the breed of lambs was significant for backfat thickness ($p<0.01$) and eye muscle area ($p<0.01$, $p<0.001$). From the Table 3 it can be observed, that the lots of crossbred lambs have the lowest backfat thickness, even if those have the highest body weight. At the same time, the lots of crossbred have the highest eye muscle area.

The diet of lambs were significant sources of variation ($p<0.05$) for the ultrasonic measurements for LD muscle depth between 3-4 lumbar vertebra and eye muscle area between 3-4 lumbar vertebra.

Table 2. Mean (± SE) for body evolution, total gain and ADG of lambs from birth to end of fattening

Specification	Genotyp				
	L1 Tsigai (M) n = 20	L2 Tsigai (M) n = 20	L3 Tsigai (F) n = 40	L4 SxBFxTi (F) n = 30	L5 SxBFxTi (M) n = 8
BW, kg	4.44 ± 0.16	4.44 ± 0.15	4.28 ± 0.10^{a}	4.62 ± 0.12^{b}	4.95 ± 0.23^{b}
WW, kg	20.16 ± 0.48^{aA}	20.17 ± 0.51^{aA}	18.22 ± 0.48^{bAD}	23.01 ± 0.56^{B}	24.90 ± 1.08^{C}
W5M, kg	42.23 ± 1.33^{aA}	40.18 ± 1.33^{A}	34.71 ± 0.94^{C}	41.83 ± 1.08^{A}	48.57 ± 2.10^{bB}
Total gain birth-weaning, kg	15.72 ± 0.69^{aA}	15.73 ± 0.69^{aA}	13.95 ± 0.49^{bA}	18.38 ± 0.56^{bB}	19.95 ± 1.09^{B}
Total gain weaning - end of fattening, kg	22.07± 0.98^{A}	20.01± 0.98^{A}	16.49 ± 0.69^{aB}	14.20 ± 0.80^{bB}	18.72 ± 1.55^{C}
Total gain birth-end of fattening, kg	37.79 ± 1.02^{aA}	35.74 ± 1.38^{A}	30.44 ± 0.93^{C}	37.21 ± 1.08^{A}	43.62 ± 2.09^{bB}
ADG birth-weaning, kg	238.10 ± 11.16^{a}	277.10 ± 11.16^{bA}	235.85 ± 7.89^{B}	306.11 ± 9.11^{acA}	334.07 ± 17.65^{C}
ADG weaning - end of fattening, kg	220.70 ± 9.37^{A}	200.05 ± 9.37^{A}	169.36 ± 6.63^{B}	137.86 ± 7.65^{AC}	187.77 ± 14.81^{D}
ADG birth-end of fattening, kg	225.83 ± 7.46^{A}	225.33 ± 7.46^{A}	193.72 ± 5.28^{B}	227.71 ± 6.09^{AC}	273.67 ± 11.80^{D}
Age at weaning, days	66.35 ± 2.06^{aA}	57.90 ± 1.82^{B}	59.63 ± 1.29^{B}	60.60 ± 1.49^{b}	58.89 ± 2.88^{b}
Age at end of fattening, days	167.35 ± 1.45^{A}	158.90 ± 2.06^{B}	156.80 ± 1.45^{BC}	163.60 ±1.68^{ABD}	157.13 ±3.25^{BCD}

Means with different superscripts ($^{a, b, c, d}$) in each traits differ (P< 0.05).
Means with different superscripts ($^{A, B, C, D}$) in each traits differ (P< 0.01 and P< 0.001).

Table 3. Mean (± SE) for ultrasound measurements of eye muscle properties and weights of lambs at end of fattening

Specification	Lot 1 n = 20 male	Lot 2 n = 20 male	Lot 3 n = 40 female	Lot 4 n = 30 female	Lot 5 n = 8 male
Fat depth on 12 rib (mm)	6.46 ± 0.25	6.96 ± 0.25^{A}	6.46 ± 0.18	6.15 ± 0.21^{B}	6.36 ± 0.40
Fat depth between 3-4 lumbar vertebra (mm)	6.44 ± 0.24^{A}	6.55 ± 0.24^{A}	6.01 ± 0.17^{A}	5.35 ± 0.19^{B}	6.12 ± 0.37
LD Muscle depth on 12 rib (mm)	23.36 ± 0.68	21.66 ± 0.68^{A}	23.27 ± 0.48	24.05 ± 0.56^{B}	24.11 ± 1.08
LD Muscle depth between 3-4 lumbar vertebra(mm)	24.24 ± 0.62^{a}	22.33 ± 0.62^{b}	22.52 ± 0.44^{b}	22.67 ± 0.51	23.28 ± 0.99
Eye muscle area on 12 rib (cm^2)	14.25 ± 0.45^{A}	13.87 ± 0.45^{A}	15.33 ± 0.32^{B}	15.84 ± 0.37^{B}	16.30 ± 0.72^{B}
Eye muscle area between 3-4 lumbar vertebra (cm^2)	13.78 ± 0.46^{a}	12.31 ± 0.46^{Ab}	13.69 ± 0.33^{ac}	14.11 ± 0.38^{B}	15.15 ± 0.73^{B}
Eye muscle perimeter on 12 rib (mm)	167.00 ± 3.16	174.25 ± 3.16	171.73 ± 2.23	174.90 ± 2.58	177.13 ± 4.99
Eye muscle perimeter between 3-4 lumbar vertebra (mm)	164.40 ± 3.12	162.10 ± 3.12	164.43 ± 2.20	167.43 ± 2.54	170.13 ± 4.93
Live weight (kg)	42.23 ± 1.33^{A}	40.18 ± 1.33^{A}	34.71 ± 0.94^{C}	41.83 ± 1.08^{A}	48.57 ± 2.10^{B}

Means with different superscripts ($^{a, b, c, d}$) in each traits differ (P<0.05).
Means with different superscripts ($^{A, B, C, D}$) in each traits differ (P<0.01 and P<0.001).

Regarding the phenotypic correlations between ultrasound measurements with weight at 5 months, from a total of 45 traits couples 46.66% are small correlation (0.00-0.30), 26.67% are medium to high correlations (0.31-0.60) and high correlations recorded 26.67% (0.61-1.00). The correlation between backfat thickness and Longissimus dorsi depth, area and perimeter were found to be negative. All others correlation were found to be positive. The correlation between Longissimus dorsi area with perimeter were highest (0.75 at 3-4 lumbar vertebrae and 0.70 at 12 rib, respectively) (Table 4). There were moderate correlations between the weight of lamb at 5 months and the measurements of Longissimus dorsi depth and area, but the correlation of weights at 5 months with backfat thickness and perimeter was lower.

Significant ($p<0.001$) differences were found between backfat thickness at 3-4 lumbar vertebrae and at 12 rib, as well between Longissimus dorsi area with depth, perimeter and body weight at 5 months.

Table 4. Correlation coefficients between ultrasound measurements and weight at 5 months (n = 118)

Traits	BFT12	BFT34	LMD12	LMD34	LMA12	LMA34	LMP12	LMP34	W5M
BFT12	1.00								
BFT34	0.43***	1.00							
LMD12	-0.02	-0.01	1.00						
LMD34	0.26	0.01	0.29	1.00					
LMA12	0.01	-0.04	0.55***	0.34***	1.00				
LMA34	0.01	0.02	0.44***	0.54***	0.70***	1.00			
LMP12	0.16	0.16	0.09	0.22	0.70***	0.42***	1.00		
LMP34	-0.01	0.10	0.26	0.20	0.51***	0.75***	0.45***	1.00	
W5M	0.21	0.08	0.36***	0.36***	0.40***	0.37***	0.27	0.20	1.00

BFT12, BFT34: BFT: Backfat Thickness; LMD12, LMD34: Longissimus Muscle Depth; LMA12, LMA34 - Longissimus Muscle Area; LMP12, LMP34 - Longissimus Muscle Perimeter; W5M - Weight at 5 Months; ***p<0.001

In this study, average lamb weight was comprised between 34.71 kg at L3 (the lot of female from Tsigai sheep) and 48.57 kg at L5 (male from crossbreed) and the average age ranged from 156 to 167 days, depending on the lot. Animal age at the time of measurement is important, as variation may exist between genetic evaluation programs which are based on ultrasonic measurements, if these scan measurements are ascertained at different time periods. Australia's genetic evaluation and performance testing program, LAMBPLAN, allows ultrasonic measurement for lambs to be taken over a wide range of ages, 5 to 18 months (Gilmour et al., 1994). Others, such as Suffolk sire-reference schemes in Canada (Gallivan & Hosford, 1997) and Britannia (MLC, 1987) target measurement at 100 and 147 days of age, respectively.

With respect to lamb weight, environmental, and genetic factors, the results observed here show differences between lots, depending on genotype and administered diet. However, the effect of diet had showed significant differences ($p<0.05$) between lots from Tsigai lambs (L1 and L2) with regard at LD muscle depth between 3-4 lumbar vertebra and eye muscle area between 3-4 lumbar vertebra. With respect at genotype, the value of crossbreed lambs appear superior with regard at body weight at birth, weaning and end of fattening, compared to the lots from Tsigai lambs. Daily gain was higher at crossbreed, and as expected, male lambs were higher performing than their female counterparts, in both genotypes (Tsigai and crossbreed lambs). The effects of genotype, sex and diet were observed in this experiment.

For the five lots of lambs that were assessed, the average backfat thickness, LD depth, LD eye muscle area and perimeter measured by ultrasound. The average backfat thickness in the two points were slower at lots of crossbreed (female and male), followed by the lot of females from Tsigai sheep, although the crossbreed registered the biggest live weight. The area of the eye muscle at 12 rib had the highest values at L5 (16.30 cm^2) followed of L4 (15.84 cm^2) and L3 (15.33 cm^2). Approximately the same tendency is maintained in the 3-4 lumbar vertebra, with the mention that here, the L1 has higher values than the L3. From the data of table 3, it is observed that the groups of females have higher values of the eye muscle area, compared to the groups of males of crossbreed (L5).

The area of the eye muscle was recorded as, 8.95, 9.67 and 10.85 cm^2 for Manchego, Merinos and Ile de France x Merino lambs, respectively, with a live weight ranging from 22 to 28 kg (Fernandez et al., 1997). The fat thickness for these genotypes was also recorded as 3.28, 3.83 and 4.10 mm, respectively. Similarly, Stanford et al. (2001) assayed 90 day old male and female lambs with live weights of 27.3 and 25.3 kg. The loin eye area was recorded as 7.15 and 7.42 cm^2 and the fat thickness of these sheep were recorded as 2.74 and 2.96 mm, respectively.

The correlation coefficients obtained in the present study are in the range previously reported in literature (Fernandez et al., 1997; Conington et al., 2001; Safari et al., 2005). Fernandez et al. (1997) stated the correlation coefficient of muscle area with muscle depth was reported as 0.56. Findings in present study were in agreement with their values. Lazar et al. (2016) had found very close correlations at Tsigai Blackhead of Teleorman between the weight at the age of 2.5 months and subcutaneous fat layer thickness, muscle depth and muscle eye area (0.72, 0.71, and 0.82, respectively). Similar results have been reported in Kivircik lambs by Ibrahim et al. (2007), who found strong correlations between body weight at birth and muscle depth (0.609) and muscle eye area (0.649). The same authors also reported strong correlations between the muscle eye area and muscle depth (0.845).

Ultrasonic measurement technology has been used in selection programs to improve growth and carcass traits in sheep (Simm et al., 1987; Larsgard & Kolstad, 2003). The advantage of this method is that it can be used on live animals at relatively low costs (Conington et al., 1995; Larsgard & Kolstad, 2003). In addition, heritability estimates for ultrasonic fat and muscle measurements were moderate to high (Fogarty, 1995; Jones et al., 2004; Safari et al., 2005). The results reported here with Tsigai and crossbreed lambs will be useful for future studies including genetic improvement of meat quality in lambs. In many parts of the world (UK, Australia, New Zealand, Denmark, Finland, Norway) ultrasound measurements are incorporated into national genetic evaluation programs or into selection indices to achieve high quality lamb carcasses (Stanford et al., 1998).

CONCLUSIONS

Lambs are being sent to market at weaning (70-90 days), or the lambs graze along with their mothers, so that the lambs are marketed at the age of 4-5 months. It is very difficult to take individual carcass measurements as lambs are generally marketed or slaughtered in small groups or individually in an unplanned manner. Ultrasonic scans on live animals may be used in breeding programs for lambs from Tsigai breed - rusty variety, along with weaning or market weight, to increase meat yield and quality of lambs. The rate of genetic improvement for growth and carcass characteristics of lambs can be accelerated by a breeding program including ultrasonic measurements along with other records, such as live weight or live weight gains in some periods.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Ministry of Agriculture and Rural Development of Romania, Department of Research and also was financed from Project ADER 8.1.1/2019.

REFERENCES

Conington, J., Bishop, S.C., Waterhouse, A., & Simm, G. (1995). A genetic analysis of early growth and ultrasonic measurements in hill sheep. *Animal Science, 61*, 85–93.

Delfa, R., Teixeira, A., Gonzalez, C., & Blasco, I. (1995). Ultrasonic estimates of fat thickness and longissimus dorsi muscle depth for predicting carcass composition of live Aragon lambs. *Small Ruminant Research*, *16,*159–164.

Emenheiser J.C., Greiner, S.P., Lewis R.M., & Notter D.R. (2010). Longitudinal changes in ultrasonic measurements of body composition during growth in

Suffolk ram lambs and evaluation of alternative adjustment strategies for ultrasonic scan data. *Journal of Animal Science, 88,* 1341–1348.

European Communities (1986). Council Directive 86/609/EEC of 24 November 1986 on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes. *Official Journal, L,* 358,1–29.

Fernández C., Gallego, L., & Quintanilla, A. (1997). Lamb fat thickness and longissimus muscle area measured by a computerized ultrasonic system. *Small Ruminant Research, 26*, 277–282.

Fernández, C., García, A., Vergara, H., & Gallego, L. (1998). Using ultrasound to determine fat thickness and longissimus dorsi area on Manchego lambs of different live weight. *Small Ruminant Research, 27*, 159–165.

Fogarty, N.M., Banks, R.G., Gilmour, A.R., & Brash L.D. (1992). Enhancement of LAMBPLAN to incorporate maternal traits and the eye muscle measurements. *Proceeding of Australian Association of Animal Breeding and Genetic, 10*, 63–66.

Fogarty, N.M. (1995). Genetic parameters for live weight, fat and muscle measurements, wool production and reproduction in sheep: A review. *Animal Breeding Abstracts, 63*, 101–143.

Gallivan, C., & Hosford, S. (1997). Environmental effect on weight, ultrasonic muscle depth and ultrasonic fat depth in Alberta Suffolk lambs. In: *Proceedings of the Annual Meeting of Canadian Society of Animal Science*, Montreal, Quebec, Canada, July 24–26.

Gilmour, A.R., Luff, A.F., Fogarty N.M., & Bariks, R. (1994). Genetic parameters for ultrasound fat depth and eye muscle measurements in live Poll Dorset sheep. *Australian Journal of Agricultural Research*, *45*, 1281–1 291.

Ibrahim, C., Orhan, K., Tufan, A., Ozdal, G., Murat, Y., & Onur, Y. (2007). Ultrasounds measurements of eye muscle properties and backfat thickness in Kivircik lambs. *Journal of Biology Science, 7*, 89–94.

Jones, H.E., Lewi, R.M., Young, M.J. & Simm, G. (2004). Genetic parameters for carcass composition and muscularity in sheep measured by X-ray computer tomography, ultrasound and dissection. *Livestock Production Science, 90,* 167–1 79.

Larsgard, A.G., & Kolstad, K., (2003). Selection for ultrasonic muscle depth; direct and correlated response in a Norwegian experimental sheep flock. *Small Ruminant Research,48,* 23–29.

Lazar, C., Gras, M. Al., Pelmus, R.S., Rotar, C.M., Ghita, E., & Burlacu, R. (2016). Estimation of meat amount by non-linear multiple regression equations using *in vivo* and carcass measurements on Teleorman Black Head lambs. *Journal of Animal and Feed Sciences, 25*, 292–301.

Leeds, T.D., Mousel, M.R., Notter, D.R., Zerby, H.N., Moffet, C.A., & Lewis, G.S. (2008). B-mode, real-time ultrasound for estimating carcass measures in live sheep: Accuracy of ultrasound measures and their relationships with carcass yield and value. *Journal of Animal Science, 86,* 3203–3214.

Mendizabal, J.A., Delfa, R., Arana, A., Eguinoa, P., Gonzalez, C., Reacher, T., & Purroy, A. (2003). Estimating fat reserves in Rasa Aragonesa ewes: A comparison of different methods. *Canadian Journal of Animal Science, 83,* 695–701.

MLC (1987). Sheep Yearbook. *Meat and Livestock Commission, Milton Keynes, UK.,* 49.

Russel, A.J.F. (1995). Ultrasonography and body composition in sheep. In: P.J. Goddard (Editor). *Veterinary Ultrasonography. CAB International. Wallingford (UK*), 315–324.

Safari, E., Fogarty, N.M., & Gilmour, A.R. (2005). A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. *Livestock Production Sciences, 92*, 271–289

Simm, G., Young, M.J., & Beatsori, P.R. (1987). An economic selection index for lean meat production in New Zealand sheep. *Animal Production, 45*, 465-475.

Stanford, K., Jones, S.D.M. & Price, M.A. (1998). Methods of predicting lamb carcass composition: A review. Small Ruminant Research, 29, 241–254.

Wilson, D.E. (1992). Application of ultrasound for genetic improvement. *Journal of Animal Science*, *70*, 973–983.