Iranian Journal of Applied Animal Science

Genetic Evaluation of some Carcass Characteristics Assessed by *in vivo* Real Time Ultrasonography in Baluchi Sheep

Research Article

A. Mohammadi[1], S. Hassani[1*], S. Zerehdaran[2], M. Bagheri[3] and A. Mirshahi[4]

[1] Department of Animal and Poultry Breeding and Genetics, Gorgan University of Agricultural Science and Natural Resources, Gorgan, Iran
[2] Department of Animal Science, Ferdowsi University of Mashhad, Mashhad, Iran
[3] Veterinary Clinic, Near Laleh Residential Complex, Asian Highway, Mashhad, Iran
[4] Department of Clinical Science, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran

Received on: 24 Jan 2018
Revised on: 25 Feb 2018
Accepted on: 15 Mar 2018
Online Published on: Sep 2018

*Correspondence E-mail: hasani@gau.ac.ir

Online version is available on: www.ijas.ir

ABSTRACT

In order to evaluate carcass characteristics of a nucleus flock of Baluchi sheep, *in vivo* ultrasound technique was used to measure backfat thickness (UBFT) and longissimus dorsi muscle area (ULMA) and also to estimate genetic parameters for these ultrasonic traits and live weights in different ages. The data were collected from 576 animals during 2011. (Co)variance components were estimated by univariate and bivariate animal models using restricted maximum likelihood and Asreml software. Females had higher UBFT and ULMA than males. Estimates of direct heritabilities were 0.32, 0.23, 0.27, 0.02, 0.12, 0.22 and 0.18 for UBFT, ULMA, birth weight (BW0), weaning weight (BW3), 6 month weight (BW6), 9 month weight (BW9) and yearling weight (BW12), respectively. There were positive and high genetic (0.68±0.15) and phenotypic (0.62±0.03) correlations between UBFT and ULMA. The genetic correlations among ultrasonic and pre 6 month weights were positive and low except for BW0 and ULMA (0.39±0.28). Contrarily, moderate to high positive genetic correlations between ultrasonic traits and weaning and post-weaning weights were found (0.33 to 0.61). Phenotypic correlations between ultrasonic and growth traits were positive and ranged from 0.09 to 0.37. High positive genetic correlation between UBFT and ULMA suggests that selection for larger muscle mass result in higher fat carcasses.

KEY WORDS backfat thickness, Baluchi sheep, genetic parameters, longissimus muscle area, ultrasound measurements.

INTRODUCTION

In Iran, red meat consumption, especially lamb and mutton is of particular importance. This is mainly due to cultural aspects or consumption habits of consumers (Sink, 1979) and also religious attitudes of Iranians. Like many countries, it seems that red meat consumption in the country is faced with new challenges. Consumers tend to lean meat and carcasses containing low fat (Kempster, 1983; Thatcher and Couchman, 1983; Stanford *et al.* 1998; Ward *et al.* 1995; Macit, 2002; Sanudo *et al.* 2000; Larsgard and Kolstad, 2003; Wood *et al.* 2007). On one hand, a minimal amount of fat (desired marbling) is essential to maintain the flavor and juiciness (Ward *et al.* 1995) and the quality of meat (Junkuszew and Ringdorfer, 2005), but on the other hand, higher animal fat in the diet increases the risk of cardiovascular disease (Department of Health, 1994; Brewer, 1994), Moreover, higher body fat content results in economic loss by increasing the feed conversion ratio (FCR), so it can lead to increased production costs (Karim, 2004; Nejati-Javaremi *et al.* 2007). Therefore, in order to meet the concerns of consumers and also demands of growing population of the country for meat products, improving the quality and quantity of sheep meat is necessary.

Among 27 Iranian native sheep breeds (Vatankhah *et al.* 2004), Baluchi sheep is the most populous with the largest distribution from central parts around the two big deserts i.e. Kavir-e-Lot and Dashte Kavir to the east regions of Iran (Shoridea, 2001). Although this breed is basically considered as a dual-purpose breed (wool and meat) but, because of the increasing economic value of meat relative to wool (Banks, 2002) and the high proportion of meat production in the overall profit, Baluchi sheep is mainly grown for meat production. For this purpose, in Mashhad Abbassabad sheep breeding center, to meet the growing demands for meat, breeding programs have been designed with the aim of producing ewes having higher litter size. Selected rams from this nucleus flock are distributed in commercial flocks. But, due to lack of suitable pasture in the region and thus ewe's inability to feed her lambs, a practical solution need to improve quantity and quality of sheep meat. Therefore, to meet consumer concerns about healthy product and also to increase carcass dressing percentage, it is necessary to shift breeding programs for selecting animals having better carcass characteristics to make rapid and stable changes in sheep carcasses.

Evaluation of carcass composition by both *in vivo* and after slaughter methods, have some restrictions. For example, Alliston (1980) showed that visual assessment of conformation is not an effective tool in long-term selection programs for selecting leaner carcasses. Swatland *et al.* (1994) introduced subjective measurements on a live animal as a technique which was not always reliable. Also, high cost of the measuring carcass traits after slaughter has restricted genetic studies about carcass traits, including estimation of genetic parameters of these traits in Iranian sheep populations. Moreover, selection for carcass traits in animals is done only through the relatives of animals, because the opportunity to choose animal is lost by gathering carcass data during the slaughter process (Maxa *et al.* 2007b).

Many researchers including Simm *et al.* (1985), Simm and Dingwall (1989), Delfa *et al.* (1995), Jones *et al.* (2004), Silva *et al.* (2005), Silva *et al.* (2006), Ripoll *et al.* (2009), Theriault *et al.* (2009) and Abdel-Mageed and Abo El-Maaty (2012) examined the effectiveness of the ultrasound technology in predicting carcass composition on live sheep and found high correlations between ultrasound and the corresponding sheep carcass characteristics measurements. Many other researchers concluded that ultrasound technology can be an appropriate tool in genetic improvement programs (Gilmour *et al.* 1994; Delfa *et al.* 1995; Thorsteinsson and Eythorsdottir, 1998; Silva *et al.* 2006; Hopkins *et al.* 2007; Sahin *et al.* 2008; Ripoll *et al.* 2009; Theriault *et al.* 2009; Orman *et al.* 2010; Agamy *et al.* 2015; Tait, 2016; Aguilar-Hernandez *et al.* 2016).

Information on carcass composition of the Iranian native sheep breeds is very scarce. To date, no research has previously been reported regarding genetic evaluation of carcass traits for Baluchi sheep. Knowing genetic parameters is the first step to develop breeding programs as well as genetic evaluation programs (Brown *et al.* 2006). Therefore, the objectives of the present study were determination of the 12/13th rib longissimus dorsi muscle (LM) area and fat depth in live Baluchi sheep by ultrasonography, and also estimation of genetic parameters of the ultrasound carcass and growth traits.

MATERIALS AND METHODS

Animal population

Data used in this experiment, were collected from Baluchi sheep of a nucleus flock of Abbasabad sheep breeding center located near to Mashhad, Iran, during 2011. All the animals, including entire yearling female and male lambs and those older than two years except for rams were recorded. Records of scanning carcass characteristics and also performance records of growth traits were collected on the 576 Baluchi sheep produced from 81 sires and 314 dams. Animals with missing records were excluded from the analyses. The data structure is presented in Table 1.

Table 1 Data structure of ultrasonic traits

Animals with records	576
No. of males	115
No. of base animals	395
Total no. of animals in the pedigree	971
Sires with progeny records	81
Dams with progeny records	449

Phenotypic measurements

Animals were ultrasound scanned for backfat thickness (UBFT) and eye muscle (longissimus thoracis et lumborum) area (ULMA) by a B mode real-time ultrasound scanner (Model:CTS 900V, SIUI, China) equipped with a multi-frequencies linear (10 MHz) probe. In order to obtain ultrasonic images, the animals were immobilized manually in standing position, wool was closely clipped from the interface between the 12th and 13th ribs lateral to the vertebral column and parallel to the rib on the left side and shaved following accurate ascertaining the scanning sites by physical palpation and then the operator applied ultrasonic gel as a conductive medium to allow maximum and better contact of the transducer head with the skin of the sheep. Capturing ultrasound images were made by placing the probe at the C site of the 12/13th rib (45 mm from the midline).

To get higher accuracy of the measurements, scanning was performed only when the animals were in a relaxed state. Real-time satisfactory images were frozen on the monitor and saved for manual analysis of tissue dimensions. Measurements were made directly from the monitor of the scanner using internal electronic calipers. From each scan image, ultrasound measurements of back-fat thickness and eye muscle area were taken.

The UBFT was measured with the skin over the eye muscle. By tracing the contours of the boundaries of eye muscle, the ULMA was measured. After making the real-time ultrasound (RTU) measurements, all the animals were also weighed to record scanning live weight (SW). Birth weight (BW0), body weight at 3 months of age (BW3) or weaning weight, body weight at 6 months of age (BW6), body weight at 9 months of age (BW9) and yearling body weight (BW12) for all the animals were also obtained from the recorded data of the flock.

Statistical analysis

To identify significant non-genetic fixed effects and covariates, data were initially analyzed using GLM procedure of SAS software (SAS, 2003). Fixed effects for both ultrasonic and growth traits were the same, except for age (SA) and live weight of each animal at scanning (SW) as covariates which were considered for ultrasound traits only. The fixed effects included in this analysis were sex (male or female), birth type (two classes i.e. single and twin), dam age (3 classes i.e. 3, 4 and 5+years old), and year of birth of lambs.

Model 1: $y_{ijklm} = \mu + S_i + BT_j + DA_k + BY_l + e_{ijklm}$

Where:
y_{ijklm}: body weight of animal.
μ: overall mean.
S_i: fixed effect of sex.
BT_j: fixed effect of birth type.
DA_k: fixed effect of dam age.
BY_l: fixed effect of birth year.
e_{ijklm}: random residual.

Model 2: $y_{ijklm} = \mu + S_i + BT_j + DA_k + BY_l + b_1(w_m) + b_2(a_m) + e_{ijklm}$

Where:
y_{ijklm}: ultrasound trait (UBFT and ULMA) of animal.
μ: overall mean.
S_i: fixed effect of sex.
BT_j: fixed effect of birth type.
DA_k: fixed effect of dam age.
BY_l: fixed effect of birth year.
w_m: weight at scanning of animal m.
b_1: regression coefficient of ultrasound traits on weight at scanning of animal m.
a_m: age at scanning of animal m.
b_2: regression coefficient of ultrasound traits on age at scanning of animal m.
e_{ijklm}: random residual.

Genetic parameters

In order to estimate variance ((co)variance) components for the studied traits, restricted maximum likelihood (REML) procedure and an animal model were used. Fixed effects of sex and birth type, birth year, dam age, age and live weight at scanning fitted as two covariates, and random direct animal additive genetic effect were included in the model. Asreml program (Gilmour *et al.* 2004) was used for the analysis. (Co)variance components were estimated using a bivariate animal model. The following linear mixed model was used for the genetic analysis:

Model 3: $y = Xb + Za + e$

Where:
y: vector of observations.
b: vector of fixed effects.
a: vector of additive random animal genetic effect.
e: vector of random residual effect.
X and Z: incidence matrices relating records to fixed and animal effects, respectively.

RESULTS AND DISCUSSION

Descriptive statistics

Descriptive statistics of the studied traits are presented in Table 2. Mean of ultrasonic fat thickness in this study was 0.44 cm in average 44.9 kg of live body weight. Kiyanzad (2004) reported carcass fat depth of 0.27 and 0.22 cm for lambs of two Iranian sheep breeds i.e. Moghani and Makui with average body weights of 38.64 kg and 36.3 kg, respectively, which were lower than the result obtained in the present investigation. As outlined by Yousefi *et al.* (2012), values of backfat depth after slaughtering were lower than corresponding ultrasound measures in the present study, i.e. 0.206 and 0.283 cm for Chall (body weight of 37.70 kg) and Zel (body weight of 35.21 kg) sheep, respectively (P<0.01). In another study on ewes of the native Churra da Terra Quente breed and male lamb crosses of Ile de France and Churra da Terra Quente, means of 0.30 and 0.31 cm for ultrasound fat thickness measured by 5 and 7.5 (MHZ) frequencies, were reported, respectively (Silva *et al.* 2006), which were slightly lower than results of the present research.

Table 2 Means and standard deviation (SD), minimum (Min) and maximum (Max), amount of variation described by the model (R^2) and coefficient of variation (CV) for the studied traits

Growth traits	Mean	SD	Min	Max	R^2	CV (%)
BW0 (kg)	4.33	0.57	2	6.5	0.31	13.10
BW3 (kg)	21.9	3.36	9	38	0.22	15.34
BW6 (kg)	30.34	4.12	17	47	0.37	13.60
BW9 (kg)	33.20	4.32	18	49	0.29	13.02
BW12 (kg)	39.26	4.96	25	57	0.41	12.65
Scanning traits						
UBFT (cm)	0.44	0.09	0.22	1.1	0.62	19.36
ULMA (cm^2)	8.80	0.93	5.15	14.7	0.64	10.58

BW0: birth weight; BW3: 3-month weight; BW6: 6-month weight; BW9: 9-month weight; BW12: 12-month weight; UBFT: ultrasound backfat thickness and ULMA: ultrasound longissimus muscle area.

Lower measures were also found by Nsoso *et al.* (2004) for UFD, i.e. 0.379, 0.308 and 0.387 centimeters for live weight at scanning of 49.46, 45.46 and 52.06 kilograms in dual purpose breeds of Border Leicester, Coopworth, and Corriedale, respectively. Ultrasound fat depth measured in a Welsh Mountain sheep population with 42.3 kg at scanning weight was 0.35 cm (Ap Dewi *et al.* 2002) which was almost in agreement with our findings, considering live weights of the animals. Moreover, measuring subcutaneous fat depth on fat-tailed Akkaraman lambs through both methods (ultrasound and on carcass) agreed well with results for Baluchi sheep (Sahin *et al.* 2008). While ultrasound fat depth of 0.45 cm for Danish Texel lambs having 41.1 kg weight at scanning was in close agreement with the results obtained for Baluchi sheep (Maxa *et al.* 2007b), they reported 0.48 cm in Shropshire lambs (38.5 kg weight) which was somewhat higher.

Leeds *et al.* (2008) also reported the mean of 0.672 cm for this trait in wether lambs which were progenies of first generation from the mating of 4 terminal sire breeds with Rambouillet ewes having body weight of 63 kg. Moreover, the average ultrasound and carcass backfat thickness in Torki-Ghashghaii male lambs were 0.56 and 0.95 cm in average body weight of 65.2 kg, respectively (Hosseini Vardanjani *et al.* 2014).

Generally, results indicated that ultrasound fat depth in Baluchi sheep as a dual purpose breed is somewhat lower than meat breeds because of intensive selection for lean production (Olesen and Husabø, 1994; Conington *et al.* 1995; Larsgard and Olesen, 1998; Husain *et al.* 2007; Maxa *et al.* 2007b).

In the experiment conducted by Kiyanzad (2005), lower lean meat content of carcasses of Baluchi sheep (with the exception of Kurdi and Sangsari lambs) compared to other fat-tailed breeds were also reported (P<0.05). Silva *et al.* (2006) found mean values of 16 (5 MHZ) and 15.6 cm^2 (7.5 MHZ) for the eye muscle area in female sheep of the native Churra da Terra Quente breed and male lamb crosses of Ile de France and Churra da Terra Quente, which were higher than means obtained for Baluchi sheep.

Sahin *et al.* (2008) reported 12.25 and 8.86 cm^2 for mean of the carcass and ultrasound eye muscle area for fat-tailed Akkaraman lambs, respectively. Leeds *et al.* (2008) reported mean of 15.9 cm^2 of cross-sectional of eye muscle in wether lambs with body weight of 63 kg. Moreover, Hosseini Vardanjani *et al.* (2014) reported area of the eye muscle measured by ultrasound and on the carcass in Torki-Ghashghaii male lambs as 15.85 and 18.69 cm^2, respectively. Higher carcass muscle area measures of 17.51 and 15.15 cm^2 than those obtained in the present study were found by Yousefi *et al.* (2012) for Chall (body weight of 37.70 kg) and Zel (body weight of 35.21 kg) sheep, respectively (P<0.05). Higher eye muscle areas for dual-purpose breeds of Chall and Zandi and their crosses with Zel breed were also found (Kashan *et al.* 2005).

Fat-tail constitutes nearly 20% of carcass weight in fat-tailed sheep (Farid *et al.* 1983; Nik-Khah, 1984). Fat-tailed sheep have low intramuscular fat (IMF) and carcass fat than tailed breeds (Khaldari *et al.* 2008; Webb and O'Neill, 2008; Atti and Mahouachi, 2011). Conversely, tailed breeds and also sheep with “normal tails” store more fat in their carcasses (Yousefi *et al.* 2012). It was also demonstrated that docking of fat-tail has been resulting in higher backfat thickness (Kashan *et al.* 2005; Khaldari and Tajic, 2006; Khaldari *et al.* 2008; Atti and Mahouachi, 2011) and greater amount of intramuscular fat (IMF) and internal fat (Donovan *et al.* 1973; Bicer *et al.* 1984; Shelton, 1990; Shelton *et al.* 1991). Hence, considering relatively small fat-tail of Baluchi breed with higher intramuscular fat (Kurdi breed) and backfat thickness (Kurdi and Sangsari breeds) than other fat-tailed sheep breeds in Iran (P<0.05) (Kiyanzad, 2005), it appears that the reduction of fat in the tail could be remedied by replacing inside the animal carcasses. According to the results, high accumulations of fat in the subcutaneous of Baluchi sheep confirm a part of fat transition from fat-tail into their carcasses. Beside, in the region, there is a public relive that Baluchi sheep meat tastes better than other breeds. IMF has been shown to be of importance in eating quality (Hopkins *et al.* 2006; Fisher *et al.* 2000) and tenderness (Warner *et al.* 2010).

Although tailed sheep deposit significantly greater IMF than fat-tailed breeds (Yousefi *et al.* 2012); but on the contrary, high IMF is equal to high proportions of saturated fatty acids (SFAs) to polyunsaturated fatty acids (PUFAs) (Fisher *et al.* 2000; Webb and O'Neill, 2008) which are correlated with increased risk of cardiovascular diseases (Grundy, 1987; Russo, 2009). It seems that the distribution of fat in Baluchi sheep carcasses resulting from fat-tail reduction has been accompanied with uniformity. Therefore, Baluchi sheep is a special breed with unique features including appropriate distribution of fat in their carcasses and tail that comply with consumer's concerns about meat quality and also meet its own biological requirements in confronting with harsh environmental conditions by fat-tail (Atti and Mahouachi, 2011; Kashan *et al.* 2005). Overall, results indicated that Baluchi sheep had carcass with lower lean meat and relatively more fat than other dual-purpose breeds at the same weight which were in accordance with the results obtained by Kiyanzad (2005).

Considering corresponding coefficients of variation, UFD was more variable than UMA. Therefore, it would be expected that change from selection to be slower in muscle than fat under similar selection intensities.

Significance of fixed effects and covariates

Results of the fixed effects significance test for the studied traits are shown in Table 3. Generally results indicated that male lambs were significantly heavier than female lambs from birth to 12 months of age. The significant effects of gender on growth traits at early ages and post-weaning periods is mainly due to the endocrine system differences between males and females. Lambs born from younger mothers had lower birth weights which can be related to the limited capacity of uterus. Furthermore, lambs carried and reared by older ewes (aged 5 and more) were significantly heavier compared with those carried by younger ewes (aged 3 and 4 years) through having dams with higher milk yield and better mothering ability and they had higher weaning and 6 months weights. Because of inadequate nutrients availability during gestation, competition for milk consumption and also unsuitable maternal supporting during pre-weaning period between twin lambs, single lambs were significantly heavier than twin lambs from birth weight to 12 months of age. The effect of birth year on body weight at 6, 9 and 12 months of age indicated that these traits had different performances over the years. Different climate conditions, diseases and condition of pasture in different years can be in charge of those variations in growth traits at different ages. For the two ultrasound traits, the effect of SW was highly significant ($P<0.0001$), while, there was no significant positive relationship between age at scanning (SA) and both scanning traits (Table 3).

Sex had significant effect on UBF ($P<0.0001$) and UMA ($P<0.05$). The two ultrasound traits were significantly affected by the birth year ($P<0.0001$). With respect to scanning traits, males had significantly lower ultrasonic fat depth and less eye muscle area than females.

Baluchi female lambs deposit greater subcutaneous fat than male lambs when UBFT adjusted for live weight which was supported by Butterfield (1988) and Stanford *et al.* (2001) in Suffolk- cross ram and ewe lambs. In other surveys, Fernandez *et al.* (1997) on Merino, Manchego, and Ile de France × Merino crosses female and male lambs with similar slaughter weights but different backfat thicknesses, Kashan *et al.* (2005) in fat tailed Chaal, Zandi, Zel × Chaal and Zel × Zandi crosses and Orman *et al.* (2010) for Awassi lambs confirmed the results of present investigation for backfat thickness.

Other researchers were also reported that ewe lambs have more Lomgissimus muscle area (LMA) compared to ram lambs (Fernandez *et al.* 1997; Stanford *et al.* 2001; Rodríguez *et al.* 2008). On the contrary, Orman *et al.* (2010) indicated that LMA values both on carcass and ultrasound-measured did not affected by sex ($P=0.20$ and $P=0.76$, respectively) for female and male lambs having 40 kg body weight. Generally, results indicated that in Baluchi breed, deposition of fat in females begin earlier than males which was in agreement with the results obtained by McClelland *et al.* (1976) and Stanford *et al.* (2001), and this is probably related to surge of fat deposition in the body when females approach 60% of mature weight. If breeding objective of the breed is producing lamb meat from slaughter male lamb, it is expected that, due to low-fat carcasses, meat production to be more cost-effective. Generally, higher fat deposition or in other words, high body condition score (BCS) of females is crucial for their reproductive efficiency (West *et al.* 1989; Rhind *et al.* 1990; Adams *et al.* 2006; Lake *et al.* 2006; Kenyon *et al.* 2010) and subsequent physiological processes such as milk yield, animal health and wellbeing (Henderson, 1990; Bewley and Schutz, 2008). In a study conducted by Abdel-Mageed and Abo El-Maaty (2012) on ewes of local Egyptian sheep breeds, there has been also a significant relationship between backfat thickness with all productive traits ($P<0.01$) and most reproductive traits including ovulation rate (OR) ($P<0.01$), ewes lambing per ewes joined, lambing rate and weaning rate ($P<0.05$). Baluchi ewes often give birth to more than one lamb per parity (average 3.28 lambs per ewe) which was reported by Abbasi *et al.* (2012). Relatively high litter size at birth can be attributed to the presence of a relationship between Baluchi ewe's fat depositions and ovulation rate (Rondon *et al.* 1996) which is a subtrait of litter size together with embryo survival, and uterine space.

Table 3 Comparison of least square means (±SE) for fixed effects in all studied traits

Fixed effect	Growth traits					Scanning traits	
	BW0 (kg)	BW3 (kg)	BW6 (kg)	BW9 (kg)	BW12 (kg)	UBFT	ULMA
Sex	****	***	****	****	****	****	*
Male	4.24^{a}±0.07	21.80^{a}±0.43	33.20^{a}±0.53	36.26^{a}±0.60	47.95^{a}±0.68	0.39^{b}±0.01	9.02^{b}±0.14
Female	3.84^{b}±0.07	20.21^{b}±0.43	28.44^{b}±0.53	31.60^{b}±0.60	36.35^{b}±0.68	0.50^{a}±0.01	9.36^{a}±0.14
Birth type	****	****	****	****	****	NS	NS
Single	4.67^{a}±0.20	23.45^{a}±1.21	33.99^{a}±1.49	36.13^{a}±1.70	44.22^{a}±1.92	0.44^{a}±0.03	9.40^{a}±0.34
Twin	3.97^{b}±0.20	20.10^{b}±1.21	31.06^{b}±1.49	33.77^{b}±1.70	42.26^{b}±1.93	0.45^{a}±0.03	9.41^{a}±0.34
Dam age	****	**	*	NS	NS	NS	NS
3	3.52^{c}±0.32	19.52^{b}±1.90	29.24^{b}±2.34	33.92^{a}±2.65	41.36^{a}±3.02	0.44^{a}±0.05	9.26^{a}±0.53
4	3.82^{b}±0.31	20.40^{a}±1.87	29.82^{b}±2.30	34.08^{a}±2.60	41.65^{a}±2.95	0.44^{a}±0.05	9.24^{a}±0.52
≥ 5	4.12^{a}±0.33	21.25^{a}±1.85	30.10^{a}±2.40	33.92^{a}±2.60	42.28^{a}±3.00	0.45^{a}±0.05	9.32^{a}±0.50
Birth year	****	NS	****	****	****	****	****
2004	3.90^{c}±0.22	19.60±1.27	28.80^{cd}±1.58	32.40^{bd}±0.03	42.97^{ab}±2.04	0.54^{a}±0.54	11.20^{a}±5.85
2005	3.87^{c}±0.14	19.10±0.84	31.77^{b}±1.03	36.06^{a}±0.03	39.66^{b}±1.33	0.53^{a}±0.44	10.13^{a}±4.80
2006	3.90^{c}±0.10	21.54±0.60	29.78^{c}±0.74	34.05^{b}±0.03	44.42^{a}±0.96	0.47^{a}±0.34	9.73^{a}±3.70
2007	4.07^{bc}±0.10	21.87±0.60	34.54^{a}±0.71	36.94^{a}±0.03	43.50^{a}±0.93	0.42^{a}±0.23	8.61^{a}±2.52
2008	4.20^{ab}±0.08	21.53±0.47	32.19^{b}±0.58	34.24^{b}±0.03	42.35^{a}±0.75	0.35^{a}±0.13	7.78^{a}±1.38
2009	4.33^{a}±0.08	21.53±0.47	27.82^{d}±0.58	29.87^{d}±0.03	39.98^{b}±0.70	0.37^{a}±0.13	7.70^{a}±1.38
Cov_{SW}	-	-	-	-	-	****	****
Cov_{SA}	-	-	-	-	-	NS	NS

BW0: birth weight; BW3: 3-month weight; BW6: 6-month weight; BW9: 9-month weight; BW12: 12-month weight; UBFT: ultrasound backfat thickness; ULMA: ultrasound longissimus muscle area; Cov_{SW}: live weight of each animal at recording of the scanning (SW) and Cov_{SA}: age of each animal at recording of the scanning traits (SA).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
* (P<0.05); ** (P<0.01); *** (P<0.001) and **** (P<0.0001).
NS: non significant.

Heritability estimates

Ultrasound traits

Estimates of components of variance and heritabilities for scanning traits are presented in Table 4. The direct heritability for fat depth was moderate (0.32). Estimates of UBFT corrected for live weight close to this value were also reported by Atkins *et al.* (1991) for 9 months of age in Poll Dorset lambs (0.32), Brash *et al.* (1992) for Corriedale sheep (0.35), Fogarty *et al.* (1994) for Hyfer sheep (0.28), and Gilmour *et al.* (1994) for 12 month of age Poll in Dorset sheep (0.33). On the contrary, lower heritability estimates were obtained by Brash *et al.* (1992) for Border Leicester (0.06) and for Gromark (0.12) and Greeff *et al.* (2003) for Merino sheep breeds (0.19). Furthermore, Maxa *et al.* (2007a) and Larsgard and Olesen (1998) found lower values of heritability for FD at weaning (0.08 and 0.05, respectively) and also Maniatis and Pollott (2002) were estimated heritability of this trait as 0.19 at 5 months of age in Suffolk lambs. Slightly higher heritability estimates for UBFT without fitting any covariate were also found in other studies (Bishop *et al.* 1996) for Scottish Blackface sheep (0.39), Saatci *et al.* (1999) for Welsh Mountain sheep (0.40), Thorsteinsson and Eythorsdottir (1998) for Icelandic sheep (0.42) and Roden *et al.* (2003) for Scottish Blackface sheep (0.44).

Ultrasound eye muscle area had moderate heritability (0.22). Gilmour *et al.* (1994) reported lower estimates of ULMA when weight at scanning included in the model for 7, 12 and 16 months of age in Poll Dorset which were 0.14, 0.12 and 0.18, respectively. Higher estimates of heritability for ULMA in studies of Moreno *et al.* (2001) for Inra401 sheep (0.57), Bibe *et al.* (2002) for French meat breed (0.59), and Greeff *et al.* (2003) for Merino sheep (0.33) were also reported. Fogarty *et al.* (2003) obtained heritability of 0.23 for merino sheep which was similar to the estimate in present investigation. Generally, moderate estimates of heritability for ultrasound measures imply enough additive genetic variation for selection programs to be effective.

Growth traits

The estimates of components of variance and heritability for growth traits are shown in Table 5. The heritability values for all the traits except for body weight in 3- months of age which was very low (0.02), were low to moderate (0.12 to 0.27).

Table 4 Estimates of components of variance and heritabilities for ultrasound traits

Trait[1]	UBFD	ULMA
σ_a^2	0.00513	0.46
σ_e^2	0.01070	1.58
σ_p^2	0.01583	2.04
h^2	0.32	0.23
SE	0.09	0.08

σ_a^2: additive genetic variance; σ_e^2: error variance; σ_p^2: phenotypic variance; h^2: heritability; UBFT: ultrasound backfat thickness and ULMA: ultrasound longissimus muscle area.
SE: standard error.

Table 5 Estimates of components of variance and heritability for growth traits using univariate model

Components of variance	Growth traits				
	Bw0	Bw3	Bw6	Bw9	Bw12
σ_a^2	0.0864	0.22	2.08	4.21	4.55
σ_e^2	0.2379	11.15	14.97	14.59	20.10
σ_p^2	0.3243	11.37	17.05	18.80	24.65
h^2	0.27	0.02	0.12	0.22	0.18
SE	0.10	0.07	0.08	0.10	0.09

BW0: birth weight; BW3: 3-month weight; BW6: 6-month weight; BW9: 9-month weight; BW12: 12-month weight; σ_a^2: additive genetic variance; σ_e^2: error variance; σ_p^2: phenotypic variance and h^2: heritability.

Birth weight
Direct heritability for the birth weight was 0.27 ± 0.10 which was somewhat higher than those reported by Yazdi *et al.* (1997) (0.14 and 0.20) for this breed and Mohammadi *et al.* (2011) (0.15) for Zandi sheep and also higher than reports of Atkins (1986) (0.13), Conington *et al.* (1995) (0.07) and Boujenane and Kansari (2002) (0.05) and more consistent with those reported by Larsgard and Olesen (1998) (0.22), Roden *et al.* (2003) (0.22) in various dual-purpose breeds of sheep. Gowane *et al.* (2010) reported higher h^2 estimates for Malpura (0.32). In addition to relatively high additive genetic variance, relatively low environmental variation due to extensive nature of the husbandry and management system can be responsible for the moderate estimate of direct heritability. However, moderate heritability suggests that birth weight of Baluchi sheep can be improved through selection programs, but because of high litter size in Baluchi ewes, this strategy can increases the risk of dystocia at lambing time.

Weaning weight
Heritability estimate for weaning weight was 0.02 ± 0.07 which was in congruence with the reports of Boujenane and Kansari (2002) for Timahdite sheep (0.06) and lower than the earlier estimates (0.19 and 0.13) reported by Yazdi *et al.* (1997) for Baluchi sheep and (0.15) by Mohammadi *et al.* (2011) for Zandi sheep.

Estimates higher than that obtained in the present study were also reported by Hall *et al.* (1995) for crossbred sheep (0.19), Saatci *et al.* (1999) for Welsh Mountain sheep (0.2), Rao and Notter (2000) for Polypay sheep (0.1), Van Vleck *et al.* (2003) for Targhee (0.18) and Gowane *et al.* (2010) for Malpura sheep (0.2).

Different heritabilities for this trait in different studies may be due to breed and environmental differences between these populations and also model used for the analysis and sampling variance.

Post weaning weights
Direct estimated heritabilities for the 6 month weight (BW6), 9 month weight (BW9), 12 month weight (BW12) were 0.12, 0.22 and 0.18, respectively. Different heritability estimate for BW6 was reported by Mohammadi *et al.* (2010) in Sanjabi sheep (0.06), Mohammadi *et al.* (2011) in Zandi sheep (0.13), Yazdi *et al.* (1997) for Baluchi sheep (0.23), Mokhtari *et al.* (2008) in Kermani sheep (0.32) and Gizaw *et al.* (2007) in Menz sheep (0.51). Estimated heritability of BW9 in the present study was in the range of values obtained in literature from low 0.03 and 0.08 in Kermani sheep (Mokhtari *et al.* 2008) and Sangsari lambs (Miraei-Ashtiani *et al.* 2007), respectively to high value of 0.59 in Afrino sheep (Snyman *et al.* 1995). A relatively higher estimate of heritability for weight at 12 months (0.26) was reported for both Targhee (Notter and Hough, 1997) and Sabi sheep (Matika *et al.* 2003). An average weighted higher estimate for BW12 (0.29) obtained by Yazdi *et al.* (1997) in this breed. Mokhtari *et al.* (2008) and Jafaroghli *et al.* (2010) have also obtained the values of 0.15 and 0.17 for direct heritability of yearling weight in Kermani and Moghani sheep, respectively. Generally, exposure of lambs to poor quality pastures after they are weaned have two consequences; firstly in such a condition lambs cannot express their genetic potential and secondly, these situations make up a large proportion of environmental variances which both together lead to decreasing heritabilities with age (Abbasi *et al.* 2012).

Moreover, pre-weaning traits tend to be influenced by maternal effects, but effectiveness of these factors on post-weaning traits is decreased as the lamb age increases (Snyman *et al*. 1995; Yazdi *et al*. 1997; Mohammadi *et al*. 2011; Abbasi *et al*. 2012).

Hence, post-weaning traits are of paramount importance to improve in breeding programs, furthermore, the traits which be measured during that time are expressing genes related to direct additive effects with high reliability (Yazdi *et al*. 1997). Low to moderate estimates of heritabilitits for body weights at different ages suggests that genetic improvement in these traits will be possible through selection programs.

Genetic and phenotypic correlations

The estimates of genetic correlation between the two scanning traits adjusted for scanning live weight are given in Table 6 which was positive and high in magnitude (0.68±0.15). Genetic correlation between UBFT and ULMA in the present study was in accordance with the estimates obtained by Gilmour *et al*. (1994) in Poll Dorset sheep which were 0.53 ± 0.24 (12 months of age) and 0.44 ± 0.39 (16 months of age).

They also reported lower genetic correlation (0.22±0.74) for 7 months of age in Poll Dorset sheep. Negative genetic correlations of -0.11 and -0.21 between carcass fat depth and carcass muscle area in Inra401 sheep were obtained by Moreno *et al*. (2001) and Bibe *et al*. (2002), respectively. A low genetic correlation was also reported by Fogarty *et al*. (2003) for Merino (0.05).

This study indicated that there is no antagonism between carcass fatness and muscularity of Baluchi sheep. These findings provide potential opportunities for genetically improving of carcass composition in Baluchi sheep.

The estimated genetic and phenotypic correlations among growth and scanning traits are summarized in Table 7. Phenotypic correlations between these two groups of traits were positive and low to moderate in magnitude.

The genetic correlations among UBFT and the growth traits were positive and moderate in magnitude, except for body weight at weaning (BW3). The genetic correlation found between BW3 and the UBFT was positive but close to zero.

Similarly, Jones *et al*. (2004) and Larsgard and Olesen (1998) reported positive genetic correlations between fat depth and body weight at different ages. In other studies, the direct negative genetic correlation between weight at weaning and fat depth were found by Maxa *et al*. (2007a) for Suffolk breed (−0.22) and Conington *et al*. (1995) (−0.21). Generally, by measuring FD in sheep having higher age, it would be expected that the genetic correlations between weight and FD be positive (Maxa *et al*. 2007a).

UMA was positively related to BW3, with the high standard errors and should be confirmed with further studies. Moreover, moderate to high genetic correlations were also observed between these scanning traits and post weaning weight.

Genetic correlations tended to be higher than the phenotypic, although interpretation of some correlations is hindered by large standard errors.

Accordance with recommendation of Koots *et al*. (1994) who declared that a minimum of 400 observations or 20 sires are required to estimate genetic parameters accurately. Although the data set of the present study was not very large, it was larger than those of other studies carried out by Cameron and Bracken (1992), Bishop (1993), Gilmour *et al*. (1994) and El Fadili *et al*. (2000).

Table 6 Estimate of phenotypic (above diagonal) and genetic (below diagonal) correlations and heritabilities (on diagonal) for scanning traits

Trait	UBFD	ULMA
UBFT	0.33±0.09	0.62±0.03
ULMA	0.68±0.15	0.23±0.08

UBFT: ultrasound backfat thickness and ULMA: ultrasound longissimus muscle area.

Table 7 Estimates of genetic and phenotypic correlations for growth and ultrasound traits

Scanning traits	Growth traits				
	BW0	BW3	BW6	BW9	BW12
Genetic					
UFD	NC[3]	0.03±0.54	0.53±0.32	0.61±0.23	0.53±0.25
UMA	0.39±0.28	0.05±0.57	0.55±0.34	0.36±0.27	0.33±0.28
Phenotypic					
UBFT	NC	0.16±0.04	0.23±0.04	0.28±0.04	0.31±0.04
ULMA	0.09±0.04	0.24±0.04	0.29±0.03	0.36±0.04	0.37±0.03

BW0: birth weight; BW3: 3-month weight; BW6: 6-month weight; BW9: 9-month weight; BW12: 12-month weight; UBFT: ultrasound backfat thickness and ULMA: ultrasound longissimus muscle area.
NC: not converged.

The results provide genetic parameter estimates for genetic evaluation programs (Brown *et al.* 2006) and the development of breeding objectives and selection indexes that include growth and ultrasound traits.

CONCLUSION

This study presents a unique opportunity to offer new knowledge on the genetics of carcass characteristics in Baluchi sheep. At present, despite of relatively high quality of wool product of Baluchi sheep, income from wool is very low because of lacking a suitable market for this product. Therefore, determination of effective breeding objectives for Baluchi sheep is becoming more complicated and genetic improvement programs may include traits with high economic values such as carcass compositions. This is the first study for genetic analysis of ultrasound measures of carcass characteristics in Iran and for more accurately estimates, further studies including more number of observations are needed. Estimates of heritabilities demonstrate moderate to high additive genetic variation for the scanning carcass traits in this population suggesting that genetic progress through selection for these traits could be achieved. The relatively high positive genetic correlation found between scanning traits suggests that selection for muscle level will result in a higher and undesirable cover of subcutaneous fat that may lead to poorer carcass quality for this breed. Favorable genetic correlations between body weight and ultrasound traits support the value of using ultrasound measurements in breeding programs, and the estimates obtained in this study can be implemented in the genetic evaluation of Baluchi sheep.

ACKNOWLEDGEMENT

We would like to thank all Abbasabad Animal Breeding Center staff for their valuable cooperation in data collection.

REFERENCES

Abbasi M.A., Abdollahi-Arpanahi R., Maghsoudi A., Vaez Torshizi R. and Nejati-Javaremi A. (2012). Evaluation of models for estimation of genetic parameters and maternal effects for early growth traits of Iranian Baluchi sheep. *Small Rumin. Res.* **104,** 62-69.

Abdel-Mageed I.I. and Abo El-Maaty A.M. (2012). The effect of backfat thickness at mating on the reproductive and productive performances of ewes. *Small Rumin. Res.* **105,** 148-153.

Adams N.R., Briegel J.R., Greeff J.C. and Bermingham E.N. (2006). Feed intake, body composition and plasma metabolic hormones in Merino sheep that differ genetically in fleece weight or fiber diameter. *Australian J. Agric. Res.* **57,** 27-32.

Agamy R., Abdel-Moneim A.Y., Abd-Alla M.S., Abdel-Mageed I.I. and Ashmawi G.M. (2015). Use of ultrasound measurements to predict carcass characteristics of Egyptian ramlambs. *Asian J. Anim. Vet. Adv.* **10(5),** 203-214.

Aguilar-Hernandez E., Chay-Canul A.J., Gomez-Vazquez A., Magaña-Monforte J.G., Ríos-Rincón F.G. and Cruz-Hernandez A. (2016). Relationship of ultrasound measurements and carcass traits in Plibuey ewes. *J. Anim. Plant Sci.* **26(2),** 325-330.

Alliston J.C. (1980). Evaluation of carcass quality in the live animal. Pp. 75-96 in Sheep Production. W. Haresign, Ed. Butterworths, London, United Kingdom.

Ap Dewi I., Saatci M. and Ulutas Z. (2002). Genetic parameters of weights, ultrasonic muscle and fat depths, maternal effects and reproductive traits in Welsh Mountain sheep. *J. Anim. Sci.* **74,** 399-408.

Atkins K.D. (1986). A genetic analysis of the components of lifetime productivity in Scottish Blackface sheep. *Anim. Prod.* **43,** 405-419.

Atkins K.D., Murray J.I., Gilmour A.R. and Luff A.L. (1991). Genetic variation in live weight and ultrasonic fat depth in Australian Poll Dorset sheep. *Australian J. Agric. Res.* **42,** 629-640.

Atti N. and Mahouachi M. (2011). The effects of diet, slaughter weight and docking on growth, carcass composition and meat quality of fat-tailed Barbarine lambs. *Rev. Trop. Anim. Health Prod.* **43(7),** 1371-1378.

Banks R.G. (2002). Enhancing the value of meat from wool sheep: Is there a need for specialisation? *Wool Technol. Sheep Breed.* **50,** 584-595.

Bewley J.M. and Schutz M.M. (2008). Review: an interdisciplinary review of body condition scoring of dairy cattle. *Prof. Anim. Sci.* **24,** 507-529.

Bibe B., Brunel J.C., Bourdillon Y., Loradoux D., Gordy M.H., Weisbecker J.L. and Bouix J. (2002). Genetic parameters of growth and carcass quality of lambs at the French progeny-test station Berrytest. Pp. 11-06 in Proc. 7th World Congr. Genet. Appl. Livest. Prod., Montpellier, France.

Bicer O., Pekel E. and Guney O. (1984). Effects of docking on growth performance and carcass characteristics of fat-tailed Awassi ram lambs. *Small Rumin. Res.* **8,** 353-357.

Bishop S.C. (1993). Selection for predicted carcass lean content in Scottish Blackface sheep. *Anim. Prod.* **56,** 379-386.

Bishop S.C., Conington J., Waterhouse A. and Simm G. (1996). Genotype × environment interactions for early growth and ultrasonic measurements in hill sheep. *Anim. Sci.* **62,** 271-277.

Boujenane I. and Kansari J. (2002). Estimates of (co)variances due to direct and maternal effects for body weights in Timahdite sheep. *J. Anim. Sci.* **74,** 409-414.

Brash L.D., Fogarty N.M., Gilmour A.R. and Luff A.F. (1992). Genetic parameters for live weight and ultrasonic fat depth in Australian meat and dual-purpose sheep breeds. *Australian J. Agric. Res.* **43,** 831-841.

Brewer M.S. (1994). Consumer attitudes toward food safety issues. *J. Food Saf.* **14,** 63-76.

Brown D.J., Ball A.J., Huisman A.E., Swan A.A., Atkins K.D., Graser H.U., Banks R.G., Swan P. and Woolaston R.R.

(2006). Sheep genetics Australia. Pp. 3-5 in Proc. 8th World Congr. Genet. Appl. Livest. Prod., Belo Horizonte, Brazil.

Butterfield R.M. (1988). New Concepts of Sheep Growth. University of Sydney Press, Sydney, Australia.

Cameron N.D. and Bracken J. (1992). Selection for carcass lean content in terminal sire breeds of sheep. *Anim. Prod*. **54,** 367-377.

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

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

Department of Health. (1994). Nutritional Aspects of Cardiovascular Disease. Report of Health and Social Subjects. London, United Kingdom.

Donovan P.B.O., Ghadaki M.B., Beheshti R.D. and Salehi B.A. (1973). Performance and carcass composition of docked and control fattailed Kellakui lambs. *Anim. Prod*. **16,** 67-76.

El Fadili M., Michaux C., Detilleux J. and Leroy P.L. (2000). Genetic parameters for growth traits of the Moroccan Timahdit breed of sheep. *Small Rumin. Res*. **37,** 203-208.

Farid A., Izadifard J., Edris M.A. and Makarechian M. (1983). Meat from culled old ewes of two fat-tailed Iranian breeds. 2. Meat, subcutaneous fat, and bone in the wholesale cuts. *Iranian Agric. Res*. **2,** 93-114.

Fernandez C., Gallego L. and Quintanilla A. (1997). Lamb fat thickness and longissimus muscle area measured by a computerized ultrasounic system. *Small Rumin. Res*. **26,** 277-282.

Fisher A.V., Enser M., Richardson R.I., Wood J.D., Nute G.R. and Kurt E. (2000). Fatty acid composition and eating quality of lamb types derived from four diverse breed × production systems. *Meat Sci*. **55(2),** 141-147.

Fogarty N.M., Brash L.D. and Gilmour A.R. (1994). Genetic parameters for reproduction and lamb production and their components and liveweight, fat depth and wool production in Hyfer sheep. *Australian J. Agric. Res*. **45,** 443-457.

Fogarty N.M., Safari E., Taylor P.J. and Murray W. (2003). Genetic parameters for meat quality and carcass traits and their correlation with wool traits in Australian Merino sheep. *Australian J. Agric. Res*. **54,** 715-722.

Gilmour A.R., Cullis B.R., Welham S.J. and Thompon R. (2004). ASREML: Program User Manual. NSW, Agriculture, Orange, Australia.

Gilmour A.R., Luff A.F., Fogarty N.M. and Banks R. (1994). Genetic parameters for ultrasound fat depth and eye muscle measurements in live Poll Dorset sheep. *Australian J. Agric. Res*. **45,** 1281-1292.

Gizaw S., Lemma S., Komen H. and Van Arendonk J.A.M. (2007). Estimates of genetic parameters and genetic trends for liveweight and fleece traits in Menz sheep. *Small Rumin. Res*. **70,** 145-153.

Gowane G.R., Chopra A., Prakash V. and Arora A.L. (2010). Estimates of (co)variance components and genetic parameters for body weights and first greasy fleece weight in Malpura sheep. *Livest. Sci*. **131,** 94-101.

Greeff J., Davidson R. and Skerritt J. (2003). Genetic relationships between carcass quality and wool production traits in Australian Merino rams. *Proc. Assoc. Adv. Anim. Breed. Genet*. **15,** 330-333.

Grundy S.M. (1987). Monounsaturated fatty acids, plasma cholesterol, and coronary heart disease. *Am. J. Clin. Nutr*. **45(5),** 1168-1175.

Hall D.G., Fogarty N.M. and Gilmour A.R. (1995). Performance of crossbred progeny of Trangie Fertility Merino and Booroola Merino rams and Poll Dorset ewes. 1. Lamb birth weight, survival and growth. *Australian J. Exp. Agric*. **35,** 1069-1074.

Henderson D.C. (1990). The Veterinary Book for Sheep Farmers. Farming Press Books, Ipswich, United Kingdom.

Hopkins D., Hegarty R., Walker P. and Pethick D. (2006). Relationship between animal age, intramuscular fat, cooking loss, pH, shear force and eating quality of aged meat from sheep. *Australian J. Exp. Agric*. **46(7),** 879-884.

Hopkins D.L., Stanley D.F. and Ponnampalam E.N. (2007). Relationship between real-time ultrasound and carcass measures and composition in heavy sheep. *Australian J. Exp. Agric*. **47,** 1304-1308.

Hosseini Vardanjani S.M., Miraei Ashtiani S.R., Pakdel A. and Moradi Shahrebabak H. (2014). Accuracy of real-time ultrasonography in assessing carcass traits in Torki-Ghashghaii sheep. *J. Agric. Sci. Technol*. **16,** 791-800.

Husain S.S., Wolf B.T. and Haresign W. (2007). Genetic parameters of lamb weights and ultrasonic muscle and fat depths in Beulah Specklefaced sheep. *Small Rumin. Res*. **70,** 116-123.

Jafaroghli M., Rashidi A., Mokhtaric M.S., Shadparvar A.A. (2010). (Co)variance components and genetic parameter estimates for growth traits in Moghani sheep. *Small Rumin. Res*. **91,** 170-177.

Jones H.E., Lewis R.M., Young M.J. and Simm G. (2004). Genetic parameters for carcass composition and muscularity in sheep measured by X-ray computer tomography, ultrasound and dissection. *Livest. Prod. Sci*. **90,** 167-179.

Junkuszew A. and Ringdorfer F. (2005). Computer tomography and ultrasound measurement as methods for the prediction of the body composition of lambs. *Small Rumin. Res*. **56(1),** 121-125.

Karim S.A. (2004). Nutrition and feeding management of sheep for mutton production. Pp. 88-99 in Proc. Natl. Semin. Opportun.Challen. Nutr. Feeding Manag. Sheep Goat. Rabbits for Sustain. Production. Central Sheep and Wool Research Institute, Avikanagar, Malpura, India.

Kashan N.E.J., Manafi Azar G.H., Afzalzadeh A. and Salehi A. (2005). Growth performance and carcass quality of fattening lambs from fat-tailed and tailed sheep breeds. *Small Rumin. Res*. **60,** 267-271.

Khaldari M., Kashan N., Afzalzadeh A. and Salehi A. (2008). Growth and carcass characteristics of crossbred progeny from lean-tailed and fat-tailed sheep breeds. *South African J. Anim. Sci*. **37(1),** 51-56.

Khaldari M. and Tajic P. (2006). Study of growth and carcass characteristics of F1 and R1 cross lambs from Zandi and Zel breeds. *J. Vet. Res*. **61(3),** 277-284.

Kashan N.E.J., Manafi Azar G.H., Afzalzadeh A. and Salehi A. (2005). Growth performance and carcass quality of fattening lambs from fat-tailed and tailed sheep breeds. *Small Rumin. Res*. **60,** 267-271.

Kempster A.J. (1983). Carcass quality and its measurement in sheep. Pp. 59-74 in Sheep Production. W. Haresign, Ed. Butterworths, London, United Kingdom.

Kenyon P.R., Morris S.T. and West, D.M. (2010). Proportion of rams and the condition of ewe lambs at joining influences their breeding performance. *Anim. Prod. Sci*. **50(6),** 454-459.

Kiyanzad M.R. (2004). Predicting carcass physical and chemical composition of Moghani and Makui sheep in breeding flocks. (body measurements and carcass characteristics). *Anim. Sci. J. (Pajouhesh and Sazandegi*). **64,** 2-11.

Kiyanzad M.R. (2005). Comparison of carcass composition of Iranian fat-tailed sheep. *Asian-Australian J. Anim. Sci*. **18(9),** 1348-1352.

Koots K.R., Gibson J.P., Smith C. and Wilton J.W. (1994). Analyses of published genetic parameter estimates for beef production traits. 1. Heritability. *Anim. Breed. Abstr*. **62(5),** 309-338.

Lake S.L., Scholljegerdes E.J., Nayigihugu V., Murrieta C.M., Atkinson R.L., Rule D.C., Robinson T.J. and Hess B.W. (2006). Effect of body condition score at parturition and postpartum supplemental fat on adipose tissue lipogenic activity of lactating beef cows. *J. Anim. Sci*. **84,** 397-404.

Larsgard A. and Kolstad K. (2003). Selection for ultrasonic muscle depth; direct and correlated response in a Norwegian experimental sheep flock. *Small Rumin. Res*. **48(1),** 23-29.

Larsgard A.G. and Olesen I. (1998). Genetic parameters for direct and maternal effects on weights and ultrasonic muscle and fat depth of lambs. *Livest. Prod. Sci*. **55,** 273-278.

Leeds T.D., Mousel M.R., Notter D.R., Zerby H.N., Moffet C.A. and 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. *J. Anim. Sci*. **86,** 3203-3214.

Macit M. (2002). Growth and carcass characteristics of male lambs of the Morkaraman breed. *Small Rumin. Res*. **43,** 191-194.

Maniatis N. and Pollott G.E. (2002). Maternal effects on weight and ultrasonically measured traits of lambs in a small closed Suffolk flock. *Small Rumin. Res*. **45,** 235-246.

Matika O., van Wyk J.B., Erasmus G.J. and Baker R.L. (2003). Genetic parameter estimates in Sabi sheep. *Livest. Prod. Sci*. **79,** 17-28.

Maxa J., Norberg E., Berg P. and Milerski M. (2007a). Genetic parameters for body weight, longissimus muscle depth and fat depth for Suffolk sheep in the Czech Republic. *Small Rumin. Res*. **72,** 87-91.

Maxa J., Norberg E., Berg P. and Pedersen J. (2007b). Genetic parameters for carcass traits and in vivo measured muscle and fat depth in Danish Texel and Shropshire. *Acta Agric. Scandinavica*. *Sect. A. Anim. Sci*. **57(2),** 49-54.

McClelland T.H., Bonaiti B. and Taylor St. C.S. (1976). Breed differences in body composition of equally mature sheep. *Anim. Prod*. **23,** 281-293.

Miraei-Ashtiani S.R., Seyedalian S.A.R. and Moradi Shahrbabak M. (2007). Variance components and heritabilities for body weight traits in Sangsari sheep, using univariate and multivariate animal models. *Small Rumin. Res*. **73,** 109-114.

Mohammadi K., Rashidi A., Mokhtari M.S. and Beigi Nassiria M.T. (2011). The estimation of (co)variance components for growth traits and Kleiber ratios in Zandi sheep. *Small Rumin. Res*. **99,** 116-121.

Mohammadi Y., Rashidi A., Mokhtari M.S. and Esmailizadeh A.K. (2010). Quantitative genetic analysis of growth traits and Kleiber ratios in Sanjabi sheep. *Small Rumin. Res*. **93,** 88-93.

Mokhtari M.S., Rashidi A. and Mohammadi Y. (2008). Estimation of genetic parameters for post-weaning traits of Kermani sheep. *Small Rumin. Res*. **80,** 22-27.

Moreno C., Bouix J., Brunel J.C., Weisbecker J.L., Francois D., Lantier F. and Elsen J.M. (2001). Genetic parameter estimates for carcass traits in the inra401 composite sheep strain. *Livest. Prod. Sci*. **69,** 227-232.

Nejati-Javaremi A., Izadi F., Rahimi G. and Moradi M. (2007). Selection in fat-tailed sheep based on two traits of fat-tail and body weight versus single-trait total body weight. *Int. J. Agric. Biol*. **l9,** 645-648.

Nik-Khah A. (1984). The growth and carcass quality of Afshari, Turkey and Mehraban lambs on different diets. *Proc. Aust. Soc. Anim. Prod*. **15,** 489-499.

Notter D.R. and Hough J.D. (1997). Genetic parameter estimates for growth and fleece characteristics in Targhee sheep. *J. Anim. Sci*. **75,** 1729-1737.

Nsoso S.J., Young M.J. and Beatson P.R. (2004). Genetic and phenotypic parameters and responses in index component traits for breeds of sheep selected for lean tissue growth. *Small Rumin. Res*. **51,** 201-208.

Olesen I. and Husabø J.O. (1994). Effect of using ultrasonic muscle depth and fat depth on the accuracy of predicted phenotypic and genetic values of carcass traits on live ram lambs. *Acta Agric. Scand., Sect. A. Anim. Sci*. **44,** 65-72.

Orman A., Caliskan G.U. and Dikmen S. (2010). The assessment of carcass traits of Awassi lambs by real-time ultrasound at different live weights and different sex. *J. Anim. Sci*. **88,** 3428-3438.

Rao S. and Notter D.R. (2000). Genetic analysis of litter size in Targhee, Suffolk, and Polypay sheep. *J. Anim. Sci*. **78,** 2113-2120.

Rhind S.M., Wetherill G.Z. and Gunn R.G. (1990). Diurnal profiles of LH, prolactin and progesterone and their interrelationships in ewes in high or moderate levels of body condition. *Anim. Reprod. Sci*. **24,** 119-126.

Ripoll G., Joy M., Alvarez-Rodriguez J., Sanz A. and Teixeira A. (2009). Estimation of light lamb carcass composition by *in vivo* realtime ultrasonography at four anatomical locations. *J. Anim. Sci*. **87,** 1455-1463.

Roden J.A., Merrell B.G., Murray W.A. and Haresign W. (2003). Genetic analysis of live weight and ultrasonic fat and muscle traits in a hill sheep flock undergoing breed improvement utilizing an embryo transfer programme. *Anim. Sci*. **76,** 367-373.

Rodríguez A.B., Landa R., Bodas R., Prieto N., Mantecon A.R. and Giraldez F.J. (2008). Carcass and meat quality of Assaf milk fed lambs: Effect of rearing system and sex. *Meat Sci*. **80,** 225-230.

Rondon Z., Forcada F., Zarazaga L., Abecia J.A. and Lozano J.M. (1996). Oestrous activity, ovulation rate and plasma melatonin concentration in Rasa Aragonesa ewes maintained at two different and constant body condition score levels and implanted or reimplanted with melatonin. *Anim. Reprod. Sci*. **41(3),** 225-236.

Russo G.L. (2009). Dietary n-6 and n-3 polyunsaturated fatty acids: From biochemistry to clinical implications in cardiovascular prevention. *Biochem. Pharmacol*. **77(6),** 937-946.

Saatci M., Dewi I.A. and Ulutas Z. (1999). Variance components due to direct and maternal effects and estimation of breeding values for 12-week weight of Welsh Mountain lambs. *Anim. Sci*. **69,** 345-352.

Sahin E., Yardimci M., Cetingul I., Bayram I. and Sengor E. (2008). The use of ultrasound to predict the carcass composition of live Akkaraman lambs. *Meat Sci*. **79,** 716-721.

Sanudo C., Alfonso M., Sanchez A., Delfa R. and Teixeira A. (2000). Carcass and meat quality in light lambs from different fat classes in the EU carcass classification system. *Meat Sci*. **56,** 89-94.

SAS Institute. (2003). SAS®/STAT Software, Release 8. SAS Institute, Inc., Cary, NC. USA.

Shelton M. (1990). Influence of docking fat tail (Karakul) sheep on lamb production. *Small Rumin. Res*. **3,** 73-76.

Shelton M., Willingham T., Thompson P. and Roberts E.M. (1991). Influence of docking and castration on growth and carcass traits of fat-tailed Karakul, Rambouillet and crossbred lambs. *Small Rumin. Res*. **4,** 235-243.

Shoridea A.R. (2001). Winter nutrition of breeding ewes with bagasse pith. MS Thesis. Ferdowsi University of Mashhad, Mashhad, Iran.

Silva S.R., Afonso J.J., Santos V.A., Monterio A., Guedes C.M., Azevedo J.M. and Dias-da-Silva A. (2006). *In vivo* estimation of sheep carcass composition using real-time ultrasound with two propes of 5 and 7.5 MHz and image analysis. *J. Anim. Sci*. **84(12),** 3433-3439.

Silva S.R., Gomes M.J., Dias-da-Silva A., Gil L.F. and Azevedo J.M.T. (2005). Estimation *in vivo* of the body and carcass chemical composition of growing lambs by real-time ultrasonography. *J. Anim. Sci*. **83,** 350-357.

Simm G., Avalos E., Dingwall W.S., King J.W.B., Parratt A.C., Owen M.G. and Cuthbertson A. (1985). Selection for improved lean meat production in Suffolk sheep – performance-test regime and use of ultrasonics and X-ray computed tomography. *Anim. Prod*. **40,** 528-529.

Simm G. and Dingwall W.S. (1989). Selection indices for lean meat production in sheep. *Livest. Prod. Sci*. **21,** 223-233.

Sink J.D. (1979). Factors influencing the flavor of muscle foods. *J. Food Sci*. **441,** 1-11.

Snyman M.A., Erasmus G.J., Van Wyk J.B. and Olivier J.J. (1995). Direct and maternal (co)variance components and heritability estimates for body weight at different ages and fleece traits in Afrino sheep. *Livest. Prod. Sci*. **44,** 229-235.

Stanford K., Bailey D.R.C., Jones S.D.M., Price M.A. and Kemp R.A. (2001). Ultrasound managements of longissimus dimensions and backfat in growing lambs: Effect of age, weight and sex. *Small Rumin. Res*. **42,** 191-197.

Stanford K., Jones S. and Price M. (1998). Methods of predicting lamb carcass composition: A review. *Small Rumin. Res*. **29,** 241-254.

Swatland H., Ananthanarayanan S. and Goldenberg A. (1994). A review of probes and robots: Implementing new technologies in meat evaluation. *J. Anim. Sci*. **72,** 1475-1486.

Tait R.G.J. (2016). Ultrasound use for body composition and carcass quality assessment in cattle and lambs. *Vet. Clin. North America. Food Anim. Pract*. **32(1),** 207-218.

Thatcher L.P. and Couchman R.C. (1983). Determining consumer requirements for lamb loin chops - a preliminary study. *Rev. Market. Agric. Econ*. **51,** 167-177.

Theriault M., Pomar C. and Castonguay F.W. (2009). Accuracy of real time ultrasound measurements of total tissue, fat, and muscle depths at different measuring sites in lamb. *J. Anim. Sci*. **87,** 1801-1813.

Thorsteinsson S. and Eythorsdottir E. (1998). Genetic parameters of ultrasonic and carcass cross-sectional measurements and muscle and fat weight of Icelandic lambs. Pp. 149-152 in Proc. 6th World Congr. Genet. Appl. Livest. Prod., Armidale, Australia.

Van Vleck L.D., Snowder G.D. and Hanford K.J. (2003). Models with cytoplasmic effects for birth, weaning, and fleece weights, and litter size, at birth for a population of Targhee sheep. *J. Anim. Sci*. **81,** 61-67.

Vatankhah M., Moradi-Shahrbabak M., Nejati-Javaremi A. Miraei-Ashtiani S.R. and Vaez-Torshizi R. (2004). A review of sheep breeding in Iran. Pp. 590-596 in Proc. 1st Congr. Anim. Aquat. Sci., Tehran, Iran.

Ward C.E., Trent A. and Hildebrand J.L. (1995). Consumer perception of lamb compared with other meats. *J. Sheep Goat Res*. **11,** 64-70.

Warner R.D., Greenwood P.L., Pethick D.W. and Ferguson D.M. (2010). Genetic and environmental effects on meat quality. *Meat Sci*. **86(1),** 171-183.

Webb E.C. and O'Neill H.A. (2008). The animal fat paradox and meat quality. *Meat Sci*. **80(1),** 28-36.

West K.S., Meyer H.H. and Sasser R.G. (1989). Ewe body condition and nutrition effects on embryonic loss. *J. Anim. Sci*. **67,** 424-431.

Wood J.D., Enser M., Fisher A.V., Nute G.R., Sheard P.R., Richardson R.I., Hughes S.I. and Whittington F.M. (2007). Fat deposition, fatty acid composition and meat quality: A review. *Meat Sci*. **78,** 343-358.

Yazdi M.H., Engstrom G., Nasholm A., Johansson K., Jorjani H. and Liljedahl L.E. (1997). Genetic parameters for lamb weight at different ages and wool production in Baluchi sheep. *Anim. Sci*. **65,** 247-255.

Yousefi A.R., Kohram H., Zare Shahneh A., Nik-khah A. and Campbell A.W. (2012). Comparison of the meat quality and fatty acid composition of traditional fat-tailed (Chall) and modern tailed (Zel) Iranian sheep breeds. *Meat Sci*. **80,** 225-230.