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

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.
lation 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 Abbasabad 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 (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

<table>
<thead>
<tr>
<th>Animals with records</th>
<th>576</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of males</td>
<td>115</td>
</tr>
<tr>
<td>No. of base animals</td>
<td>395</td>
</tr>
<tr>
<td>Total no. of animals in the pedigree</td>
<td>971</td>
</tr>
<tr>
<td>Sires with progeny records</td>
<td>81</td>
</tr>
<tr>
<td>Dams with progeny records</td>
<td>449</td>
</tr>
</tbody>
</table>

### Phenotypic measurements

Animals were ultrasound scanned for backfat thickness (UBFT) and eye muscle (longissimus thoracis et lumbarum) 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.

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

Where:
- \( y_{ijklm} \): body weight of animal.
- \( \mu \): 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.
- \( \mu \): 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, 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.
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 cm² (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 cm² 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 cm² 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 cm², respectively. Higher carcass muscle area measures of 17.51 and 15.15 cm² 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).

### 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

<table>
<thead>
<tr>
<th>Growth traits</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>$R^2$</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW0 (kg)</td>
<td>4.33</td>
<td>0.57</td>
<td>2</td>
<td>6.5</td>
<td>0.31</td>
<td>13.10</td>
</tr>
<tr>
<td>BW3 (kg)</td>
<td>21.9</td>
<td>3.36</td>
<td>9</td>
<td>38</td>
<td>0.22</td>
<td>15.34</td>
</tr>
<tr>
<td>BW6 (kg)</td>
<td>30.34</td>
<td>4.12</td>
<td>17</td>
<td>47</td>
<td>0.37</td>
<td>13.60</td>
</tr>
<tr>
<td>BW9 (kg)</td>
<td>33.20</td>
<td>4.32</td>
<td>18</td>
<td>49</td>
<td>0.29</td>
<td>13.02</td>
</tr>
<tr>
<td>BW12 (kg)</td>
<td>39.26</td>
<td>4.96</td>
<td>25</td>
<td>57</td>
<td>0.41</td>
<td>12.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scanning traits</th>
<th>UBFT (cm)</th>
<th>ULMA (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.44</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td>0.09</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>0.22</td>
<td>5.15</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>14.7</td>
</tr>
<tr>
<td></td>
<td>0.62</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>19.36</td>
<td>10.58</td>
</tr>
</tbody>
</table>

**Notes:**
- UBFT: ultrasound backfat thickness
- ULMA: ultrasound longissimus muscle area.
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 UBF 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; Rodriguez 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.
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 Largsard 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 Intra401 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 3: Comparison of least square means (±SE) for fixed effects in all studied traits

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>BW0 (kg)</th>
<th>BW3 (kg)</th>
<th>BW6 (kg)</th>
<th>BW9 (kg)</th>
<th>BW12 (kg)</th>
<th>UBFT</th>
<th>ULMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>*</td>
</tr>
<tr>
<td>Male</td>
<td>4.24±0.07</td>
<td>21.80±0.43</td>
<td>33.20±0.53</td>
<td>36.26±0.60</td>
<td>47.95±0.68</td>
<td>0.39±0.01</td>
<td>9.02±0.14</td>
</tr>
<tr>
<td>Female</td>
<td>3.84±0.07</td>
<td>20.21±0.43</td>
<td>28.44±0.53</td>
<td>31.60±0.60</td>
<td>36.35±0.68</td>
<td>0.50±0.01</td>
<td>9.36±0.14</td>
</tr>
<tr>
<td>Birth type</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Single</td>
<td>4.67±0.20</td>
<td>23.45±1.21</td>
<td>33.99±1.49</td>
<td>36.13±1.70</td>
<td>44.22±1.92</td>
<td>0.44±0.03</td>
<td>9.40±0.34</td>
</tr>
<tr>
<td>Twin</td>
<td>3.97±0.20</td>
<td>20.10±1.21</td>
<td>31.06±1.49</td>
<td>33.77±1.70</td>
<td>42.26±1.93</td>
<td>0.45±0.03</td>
<td>9.41±0.34</td>
</tr>
<tr>
<td>Dam age</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>≥5</td>
<td>4.12±0.33</td>
<td>21.25±1.85</td>
<td>30.10±2.40</td>
<td>33.92±2.60</td>
<td>42.28±3.00</td>
<td>0.45±0.05</td>
<td>9.32±0.50</td>
</tr>
<tr>
<td>Birth year</td>
<td>****</td>
<td>NS</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>2004</td>
<td>3.90±0.22</td>
<td>19.60±1.27</td>
<td>28.80±1.58</td>
<td>32.40±2.03</td>
<td>42.97±2.04</td>
<td>0.54±0.54</td>
<td>11.20±5.85</td>
</tr>
<tr>
<td>2005</td>
<td>3.87±0.14</td>
<td>19.10±0.84</td>
<td>31.77±1.03</td>
<td>36.06±0.03</td>
<td>39.66±1.33</td>
<td>0.53±0.44</td>
<td>10.13±4.80</td>
</tr>
<tr>
<td>2006</td>
<td>3.90±0.10</td>
<td>21.54±0.60</td>
<td>29.78±0.74</td>
<td>34.05±0.33</td>
<td>44.42±0.96</td>
<td>0.47±0.34</td>
<td>9.73±3.70</td>
</tr>
<tr>
<td>2007</td>
<td>4.07±0.10</td>
<td>21.87±0.60</td>
<td>34.54±0.71</td>
<td>36.94±0.03</td>
<td>43.50±0.93</td>
<td>0.42±0.23</td>
<td>8.61±2.52</td>
</tr>
<tr>
<td>2008</td>
<td>4.20±0.08</td>
<td>21.53±0.47</td>
<td>32.19±0.58</td>
<td>34.24±0.03</td>
<td>42.35±0.75</td>
<td>0.35±0.13</td>
<td>7.78±1.38</td>
</tr>
<tr>
<td>2009</td>
<td>4.33±0.08</td>
<td>21.53±0.47</td>
<td>27.82±0.58</td>
<td>29.87±0.03</td>
<td>39.98±0.70</td>
<td>0.37±0.13</td>
<td>7.70±1.38</td>
</tr>
<tr>
<td>Cov SW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>Cov SA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

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.
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
Heredity 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 Ker mani 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).

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

<table>
<thead>
<tr>
<th>Trait</th>
<th>UBFD</th>
<th>ULMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma^2_a$</td>
<td>0.00513</td>
<td>0.46</td>
</tr>
<tr>
<td>$\sigma^2_e$</td>
<td>0.01070</td>
<td>1.58</td>
</tr>
<tr>
<td>$\sigma^2_p$</td>
<td>0.01583</td>
<td>2.04</td>
</tr>
<tr>
<td>$h^2$</td>
<td>0.32</td>
<td>0.23</td>
</tr>
<tr>
<td>SE</td>
<td>0.09</td>
<td>0.08</td>
</tr>
</tbody>
</table>

$\sigma^2_a$: additive genetic variance; $\sigma^2_e$: error variance; $\sigma^2_p$: phenotypic variance; $h^2$: heritability; UBFT: ultrasound backfat thickness and ULMA: ultrasound longissimus muscle area.

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

<table>
<thead>
<tr>
<th>Components of variance</th>
<th>Bw0</th>
<th>Bw3</th>
<th>Bw6</th>
<th>Bw9</th>
<th>Bw12</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma^2_a$</td>
<td>0.0864</td>
<td>0.22</td>
<td>2.08</td>
<td>4.21</td>
<td>4.55</td>
</tr>
<tr>
<td>$\sigma^2_e$</td>
<td>0.2379</td>
<td>11.15</td>
<td>14.97</td>
<td>14.59</td>
<td>20.10</td>
</tr>
<tr>
<td>$\sigma^2_p$</td>
<td>0.3243</td>
<td>11.37</td>
<td>17.05</td>
<td>18.80</td>
<td>24.65</td>
</tr>
<tr>
<td>$h^2$</td>
<td>0.27</td>
<td>0.02</td>
<td>0.12</td>
<td>0.22</td>
<td>0.18</td>
</tr>
<tr>
<td>SE</td>
<td>0.10</td>
<td>0.07</td>
<td>0.08</td>
<td>0.10</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Bw0: birth weight; Bw3: 3-month weight; Bw6: 6-month weight; Bw9: 9-month weight; Bw12: 12-month weight; $\sigma^2_a$: additive genetic variance; $\sigma^2_e$: error variance; $\sigma^2_p$: phenotypic variance and $h^2$: heritability.
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 heritabilities 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.

According to the 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>
<thead>
<tr>
<th>Trait</th>
<th>UBFD</th>
<th>ULMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>UBFT</td>
<td>0.33±0.09</td>
<td>0.62±0.03</td>
</tr>
<tr>
<td>ULMA</td>
<td>0.68±0.15</td>
<td>0.23±0.08</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Scanning traits</th>
<th>BW0</th>
<th>BW3</th>
<th>BW6</th>
<th>BW9</th>
<th>BW12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFD</td>
<td>NC</td>
<td>0.03±0.54</td>
<td>0.53±0.32</td>
<td>0.61±0.23</td>
<td>0.53±0.25</td>
</tr>
<tr>
<td>UMA</td>
<td>0.39±0.28</td>
<td>0.05±0.57</td>
<td>0.55±0.34</td>
<td>0.36±0.27</td>
<td>0.33±0.28</td>
</tr>
<tr>
<td>Phenotypic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UBFT</td>
<td>NC</td>
<td>0.16±0.04</td>
<td>0.23±0.04</td>
<td>0.28±0.04</td>
<td>0.31±0.04</td>
</tr>
<tr>
<td>ULMA</td>
<td>0.09±0.04</td>
<td>0.24±0.04</td>
<td>0.29±0.03</td>
<td>0.36±0.04</td>
<td>0.37±0.03</td>
</tr>
</tbody>
</table>

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 growth through selection for these traits could be achieved. The results provide genetic parameter estimates for genetic evaluation programs and the estimates obtained in this study can be implemented in the genetic evaluation of Baluchi sheep.

ACKNOWLEDGEMENT

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REFERENCES


Khaldari M. and Tajic P. (2006). Study of growth and carcass characteristics of F1 and R1 cross lambs from Zandi and Zel...


