Review article

Growth and carcass characteristics of Icelandic lambs – a review

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ABSTRACT

Studies on weight and carcass characteristics of Icelandic lambs are reviewed with emphasis on genetic parameters and genetic improvement. Direct heritability of weaning weight was found to be 0.15-0.29 and 0.11-0.18 for carcass weight. Maternal heritability was 0.27 and 0.24 for weaning weight and carcass weight, respectively. Carcass measurements representing shape and size of the carcass were highly heritable, while cross-sectional measurements of muscle and fat thickness have high or medium-high heritability. Ultrasonic measurements of fat and muscle thickness of live lambs have a heritability of 0.42-0.56, with high genetic correlations with carcass measurements of muscle and fat. Ultrasound measurements have been used as selection criteria in the national breeding scheme, as well as breeding values for carcass classification scores. Selection for more compact animals has changed the conformation of the breed in the past 50 years. Significant genetic improvement has been documented, yielding increased muscling and decreased fat of lamb carcasses.

Keywords: Icelandic sheep, weaning weight, carcass quality, heritability

YFIRLIT

Vöxtur og skrokkeiginleikar íslenskra lamba – yfirlit

Í greininni er tekið saman yfirlit um rannsóknir á þunga og vaxtarlagi íslenskra lamba með áherslu á erfðastuðla og kynbætur. Arfgengi beinna áhrifa á haustþunga er á bilinu 0,15-0,29 og 0,11-0,18 fyrir fallþunga. Arfgengi mæðraáhrifa er metið 0,27 fyrir haustþunga og 0,24 fyrir fallþunga. Skrokkmælingar sem lýsa stærð og vaxtarlagi skrokka hafa almennt hátt arfgengi og þverskurðarmælingar á vöðva- og fituþykkt hafa meðalhátt og hátt arfgengi. Ómsjármælingar á þykkt vöðva og fitu á lifandi lömbum hafa arfgengið 0,42-0,56 og hafa meðalháa og háa erfðafylgni við hliðstæðar mælingar á skrokkum. Þessar mælingar eru nýttar sem úrvalsskilyrði í kynbótastarfinu ásamt kynbótamati fyrir kjötmatsflokka. Skipulegt úrval fyrir þéttri byggingu hefur breytt vaxtarlagi fjárstofnsins á sl. 50 árum. Sýnt hefur verið fram á verulegar erfðaframfarir í átt að vöðvameiri og fituminni skrokkum.

INTRODUCTION

The Icelandic sheep is a landrace that belongs to the short-tailed group of North European sheep and has its closest relatives in Norwegian short-tailed sheep (Adalsteinsson 1981, Tapio et al. 2005). The breed has been the only sheep breed in the country since the settlement around 900 AD (Adalsteinsson 1981), and attempts to improve the breed by imported stock have not left a detectable genetic influence (Tapio et al. 2005). A recent survey shows that the Icelandic sheep are the largest population of short-tailed sheep with a total number of 500,000 animals worldwide, with more than 90% raised in Iceland (Dýrmundsson & Niznikowski 2010). Sheep were mainly kept for milk and wool until the early 20th century when meat became the most valuable product (Torfason & Jónmundsson 2000). The production system is based on spring lambing and rangeland grazing in the summer followed by weaning and slaughter of lambs, often directly from rangeland pasture. Attempts to improve growth and conformation of sheep by selection started with the work of Dr Halldór Pálsson in the 1940s (Pálsson 1983), where he utilized results from his research on growth and development of sheep in Scotland (Pálsson 1939). Organized breeding was built up with a central database around 1970. There has always been a strong emphasis on lamb growth in the breeding work, using carcass weight as a selection criterion rather than live weight (Jónmundsson 1986), while conformation and carcass characteristics have gained increasing importance with emphasis on lean growth and reduced fat in recent decades (Thorsteinsson 2002). In the current paper the main results from studies on growth and carcass characteristics of the Icelandic breed are reviewed with special reference to genetic improvement.

WEANING WEIGHT AND CARCASS WEIGHT

Studies of lamb growth have focused on weaning weight and measurements of live lambs in autumn, as well as carcass weight. Pálsson & Thorsteinsson (1973) analysed the birth weight, weaning weight and carcass weight of 1845 lambs in a progeny testing scheme. They found that lambs multiplied their live weight in 133 days from birth to weaning by a factor of 10.4 and 11.0 for singles and twins, respectively, while carcass weight was found to be 4.3 times birth weight, equal for both birth types. It was also concluded from carcass measurements that heavy lambs at birth had longer bones and thinner muscles than lighter lambs and thus less desirable carcass characteristics.

Environmental effects on weaning weight and carcass weight were reported by Jónmundsson (1976a) based on data from experimental farms, where age of lamb, age of dam, type of birth and sex of lamb explained 46% of the variation in weaning weight within flock and year. A more extensive study of data from the national recording scheme showed that the most important factors were sex of lamb and type of birth and rearing, which explained 25% of the variation in weaning weight within flock and year, while the full model including age of lamb and age of dam explained 39% (Jónmundsson 1977a). The average difference between singles and twins was found to be 6.35 kg at weaning and 2.82 kg between entire ram lambs and ewe lambs. The sex difference was, however, found to be better described as a proportion where the ram lambs were on average 8% heavier than the ewe lambs (Jónmundsson 1977a).

Heritability of weaning weight and carcass weight has been estimated in several studies and an overview is given in Table 1. All studies except for one were based on rather limited data (<8000 records) and those estimates have relatively high standard errors. Estimates of direct heritability ranged from 0.15 to 0.29 for weaning weight and 0.11 to 0.18 for carcass weight. Two of three estimates of maternal heritability were higher than the direct heritability. One estimate of the direct-maternal genetic correlation of weaning weight of -0.43 has been published (Jónmundsson 1981).

A ewe production index (EPI) based on weaning weight of lambs was first suggested by Adalsteinsson (1966) and later taken up as a measurement of maternal ability in the recording scheme (Jónmundsson 1986). The index is based on total litter weight weaned by the ewe in each production year after adjustments for litter size and environmental factors. The heritabilities of two production indexes based on weaning weight and carcass weight were estimated at 0.22 and 0.21, respectively, with a genetic correlation of 0.9. The analysis included data on 26,144 ewes where performance in different parities was combined and analysed as a single trait (Jónmundsson 1977b). Later

Table 1. Heritability estimates of weaning weight and carcass weight of Icelandic lambs.

Trait	Records	h^2 direct	h^2 maternal	Reference
Weaning weight				
- ram lambs[1)]	6,326	0.19	0.27	Jónmundsson 1976b
- ewe lambs	6,645	0.29	0.27	Jónmundsson 1976b
- both sexes	50,996	0.20	-	Jónmundsson 1977a
- ram lambs	7,088	0.15	-	Adalsteinsson & Jónmundsson 1978
- ewe lambs	7,396	0.24	-	Adalsteinsson & Jónmundsson 1978
- ram lambs	1,826	0.18	-	Thorsteinsson & Björnsson 1982
Carcass weight				
- both sexes	42,888	0.13	-	Jónmundsson 1977a
- ram lambs	1,826	0.11	-	Thorsteinsson & Björnsson 1982
- both sexes	3,463	0.18	0.24	Eythórsdóttir 1999
- ram lambs	2,104	0.17		Thorsteinsson 2002

[1)] Data from entire ram lambs in all studies

Árnason & Jónmundsson (2008) analysed data on 193,213 ewes in the national records with a multitrait model including four parities as separate traits and obtained heritability estimates of 0.15-0.18.

CARCASS CHARACTERISTICS

Information on carcass traits has mainly been obtained from the programme of progeny testing of rams at the Hestur Experimental Farm that has been in operation since 1957. The programme has been described in detail by Thorsteinsson & Björnsson (1982), Thorsteinsson (1983b) and Thorsteinsson (2002). Briefly, the programme includes progeny testing of rams that are mated to a minimum of 20 ewes. All ram lambs in the progeny groups are slaughtered directly from rangeland pasture the following autumn and carcass quality traits measured. Up to 27 measurements were made on each carcass during the first 20 years, but later the number of measurements has been reduced. External measurements were designed to describe the shape of the carcass, length, width and depth measurements and derived ratios, while cross-sectional measurements represent dimensions of the eye muscle (*l. dorsi*) and fat thickness at the 12th rib. The most frequently used cross-sectional measurements were defined by Pálsson (1939):

A: width of eye muscle (*l.dorsi*) measured across from the spinal cord and outwards
B: depth of eye muscle at right angles to A
C: thickness of back fat over the deepest part of the eye muscle
J: thickest layer of fat over the 12th rib

A detailed study of growth and development of Icelandic sheep, summarized by Thorgeirsson & Thorsteinsson (1989), confirmed clear differences in tissue proportions of carcasses from lambs of two conformation types, characterized as short-legged and long-legged. Carcasses from the short-legged type had a higher muscle:bone ratio, lighter bones and more fat at equal carcass weight, while differences in muscle proportions were less conclusive. Differences in the ratios of muscle:bone and fat:bone were evident for equal carcass fatness, indicating true type effects, in addition to effects from unequal stages of maturity. Considerable variation was found, however, between animals within these categories.

Genetic parameters of a large number of carcass traits have been estimated on data from the progeny testing programme and selected results are shown in Table 2. Thorsteinsson & Björnsson (1982) made a comprehensive analysis of 27 carcass traits using data from 1958-1977. All external carcass measurements, representing leg length and width of the carcass, were highly heritable ($h^2 > 0.4$) with low coefficients of variation (CV) while cross-sectional measurements indicative of tissue thickness were found to be moderately heritable with a rather high CV. Correlations within groups of measurements showed that related measurements were often highly correlated and subsequently the number of measured traits in the progeny testing programme was reduced (Thorsteinsson 2002). Comparisons of results from two periods (Table 2) show that considerable changes have been achieved over time towards shorter and more compact carcass conformation. The heritability of external carcass measurements was generally lower in the later period, indicating reduced genetic variation within the flock, although phenotypic variances were slightly higher for most traits in the later period, whereas heritability of cross-sectional measurements had increased. Up to 1980 the main selection emphasis was placed on short legs and bulky conformation, using cannon bone length as the main selection criterion while lean carcasses and reduced fat were the main selection criteria in later years (Thorsteinsson 2002).

The carcass measurements were used to build prediction equations for tissue composition of carcasses by Thorgeirsson & Thorsteinsson (1986). The best prediction models (R^2 = 0.96-0.97) for both lean and fat content included carcass weight, the J measurement and the approximate area of the eye muscle (A x B). The J measurement was found to be the most useful predictor of fat, together with carcass weight, and the use of this measurement was recommended as a tool in carcass classification with respect to fatness.

The genetic correlations between fat measurements and muscle thickness are of special interest when selection is aimed at high lean content and Thorsteinsson & Björnsson (1982) reported negative genetic correlations between C and B measurements, whereas the opposite was found for J and B. Both fat measurements were positively correlated to muscling of the leg (leg score). Results from the second period up to 1996 (Table 2) showed negative genetic correlations between J and both dimensions of the eye muscle (Thorsteinsson 2002). The change in both heritability and genetic correlations was explained by a strong selection against side fat, which increased the contribution of animals representing a late maturing type that combined lean carcasses and low fat content (Thorsteinsson 2002). This type was first identified by Árnason & Thorsteinsson (1982) in a principal component analysis of all

Table 2. Mean values, phenotypic standard deviations (σ_p) and heritability (h^2) of carcass traits measured in the progeny testing programme at the Hestur Experimental Farm over two periods (Thorsteinsson & Björnsson 1982, Thorsteinsson 2002).

		1957-1977 N=1826			**1978-1996 N=2104**	
Trait	**mean**	σ_p	h^2	**mean**	σ_p	h^2
Crutch depth (F), mm	260.6	9.95	0.75	245.9	11.17	0.61
Thorax depth (Th), mm	258.2	6.22	0.67	251.8	6.25	0.61
Width of chest (V), mm	156.8	5.78	0.38	162.7	7.01	0.34
Shape of chest (V/Th)	0.61	0.03	0.56	0.65	0.04	0.43
Leg score (1-5)	2.84	0.62	0.54	3.61	0.56	0.69
Width of *l. dorsi* (A) mm	51.76	3.06	0.44	54.14	3.21	0.56
Depth of *l.dorsi* (B) mm	22.09	2.07	0.32	24.53	2.21	0.40
Shape of *l. dorsi* (B/A)	0.43	1.33	0.36	0.45	1.57	0.54
Area of *l.dorsi* (A x B) mm^2	11.46	0.05	0.36	13.33	0.05	0.29
Fat depth on loin (C), mm	2.42	1.17	0.32	2.35	1.22	0.53
Fat depth on rib (J), mm	6.00	1.80	0.28	7.15	1.90	0.52
Cannon bone wt, g	34.71	2.29	0.53	33.28	2.13	0.79
Cannon bone length, mm	116.5	3.77	0.82	111.6	3.56	0.64
Cannon bone circumf., mm	42.47	1.83	0.41	43.35	1.53	0.54

carcass traits measured, and animals representing this type were subsequently utilised heavily in the selection of the breeding flock. A progeny comparison of so-called lean-type sires and conventional sires showed clear differences in muscularity and fat content of ram lamb carcasses estimated from carcass measurements (Thorsteinsson 2002). Further studies of the two types included full dissection of carcasses into fat, muscle and bones where these differences were confirmed, as shown in Table 3, although these results only represent the progeny of one sire of each type (Thorsteinsson 2002).

Table 3. Proportions[1)] of fat, lean and bone in carcass halves of lambs sired by two sires representing a lean type (sire 969) and conventional type (sire 883), adjusted to equal carcass weight. (adapted from Thorsteinsson 2002).

	Lean type sire 969	**Conv. type sire 883**
Number of carcasses	31	25
Total carcass fat	0.188	0.234
Total carcass lean	0.625	0.576
Total bone	0.130	0.130

[1)] Proportions do not sum to 1 due to dissection wastage.

The EUROP system of classification of lamb carcasses was taken up in Iceland in 1998 (Reglugerð um gæðamat, flokkun og merkingu sláturafurða nr. 882/2010), where carcasses are classified according to conformation and fat on a 5 point scale for conformation and a 6 point scale for fat. The fat classification is partly dependent on a measurement of tissue depth over the 12th rib (GR), which is highly correlated to the J measurement. The GR measurement is made on the whole carcass using a digital needle probe that measures tissue thickness over the rib (Einarsdóttir 1998), while the J measurement is a cross-sectional fat measurement. A comparison made by Einarsdóttir (1998) showed that the GR measurement had a similar prediction ability of fat and lean content in the carcass as the J measurement, both measured on cold carcasses. Heritability of the EUROP scores (transformed to a numerical scale of 2-14) was estimated from data collected in the first year when the system was in use and found to be 0.40 and 0.27 for conformation and fat class, respectively, with a genetic correlation of 0.48 (Sævarsson 1999). The EUROP scores have been found to be significantly related to carcass weight, with higher scores for both conformation and fat with increased weight, and ewe lamb carcasses get higher fat scores than ram lambs at equal carcass weights (Jónsdóttir & Eythórsdóttir 2009). Breeding values for the EUROP scores have been estimated since 1999 and used as selection criteria in the national breeding scheme, especially for rams selected for artificial insemination (AI) (Jónmundsson & Sigurdsson 1999). Genetic gain in terms of estimated breeding values for animals born in 1993 to 2004 was reported by Örnólfsson et al. (2007) and selection for carcass conformation was found to have yielded more response than selection against fat. This result was explained by the positive, but undesirable, genetic correlation between the traits. However, the increasing use of lean-type sires in AI was shown to have yielded a stronger selection response against fat within the group of AI sires than in the whole breeding population (Örnólfsson et al. 2007).

LIVE ANIMAL MEASUREMENTS

Traits measured on live animals are valuable selection criteria given that they are genetically related to carcass traits. Thorsteinsson (1983a) reported heritabilities of measurements and conformation scores of live animals and correlations with carcass traits. The traits measured on live lambs included heart girth (chest circumference), width of loin, cannon bone length and conformation scores for loin and legs. All conformation traits were highly heritable ($h^2 > 0.35$) except for loin width. Scores for loin and leg were highly genetically correlated and both had positive genetic correlations with B and fat measurements but were negatively related to the A measurement. Cannon bone length (*in vivo*) was found to be the same trait as the bone measurement made after

Table 4. Estimates of heritability (h^2) of ultrasonic measurements of muscle depth (UMD) and fat depth (UFD) at the 3rd lumbar vertebra, together with live measurements of conformation and genetic correlations with selected carcass measurements (see Table 2 for abbreviations).

Trait	N	h^2	Genetic correlations with A	B	C	J	Reference[1)]
UMD	803	0.55					1
	2946	0.42	0.38	0.94	-0.32	-0.11	2
UFD	803	0.56					1
	2946	0.42	-0.43	-0.17	0.85	0.69	2
Leg score (1-5)	955	0.47	-0.60	0.51	0.57	0.66	3
Loin score (1-5)	955	0.59	-0.44	0.58	0.44	0.63	3
Cannon bone length	955	0.64	0.39	-0.45	-0.12	-0.44	3

[1)] 1: Thorsteinsson et al., 1994 2: Thorsteinsson & Eythórsdóttir, 1998 3: Thorsteinsson, 1983a

slaughter with a genetic correlation of 0.98. Heart girth was positively related to carcass frame size.

The usefulness of ultrasonic measurements of live animals was investigated by Thorsteinsson, Thorgeirsson & Einarsdóttir (1994). Live weight and muscle depth measured ultrasonically at the 3rd lumbar vertebra were found to explain 86% of the variation in lean content measured by anatomical dissection of carcasses into muscle, fat and bone (n=86 ram lambs). Similarly, 82% of the variation in fat content was explained by live weight and ultrasonic measurements of fat depth. A recent study based on a less detailed boning method of 183 carcasses showed that ultrasonic measurements of fat and muscle depth alone explained 34% of variation in lean meat yield. Live weight and scores for conformation of chest and legs on live animals added little to the explanation ratio of the prediction model (Einarsson et al. 2009). Heritability of ultrasonic measurements reported for the Icelandic lambs is shown in Table 4, together with genetic correlations between these and selected carcass measurements.

FUTURE PROSPECTS

The Icelandic sheep, together with the Faeroe sheep, are the only North European short-tailed breeds that are still in use as major production breeds in their home countries and the Icelandic sheep are by far the largest population within this group of breeds. The extensive research work that has been carried out to define and improve the carcass characteristics of the breed has definitely played a major role in keeping up the quality of the lamb production and making it possible for the industry to follow market demands. Significant changes have been achieved towards leaner carcasses with desirable conformation by utilising the genetic variation found within the breed. Given the increased knowledge of the genetics behind the tissue composition of meat-producing animals, further investigation of the lean genotype of animals that have played a key role in this development is not only of interest but easily possible. The growth rate of lambs has not changed as markedly as the carcass traits during recent decades and there seems to be an opportunity for genetic improvement of autumn weight in view of the genetic variation found. The growth rate, however, is strongly affected by environmental conditions and phenotypic change may not always be observed, although genetic progress for growth rate has been realized.

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