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A. M. van Heelsum

Animal Biology Division, SAC, King's Buildings, Edinburgh, a.vanheelsum@ed.sac.ac.uk

R. M. Lewis

Scottish Agricultural College, ron.lewis@unl.edu

M. H. Davies

ADAS Rosemaund

W. Haresign

University of Wales, Aberystwyth

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Growth and carcass characteristics in wether lambs of a crossbred dam line

A. M. van Heelsum^{1†}, R. M. Lewis^{1‡}, M. H. Davies² and W. Haresign³

¹Animal Biology Division, Scottish Agricultural College, King's Buildings, West Mains Road, Edinburgh EH9 3JG, UK

²ADAS Rosemaund, Preston Wynne, Hereford HR1 3PG, UK

³Institute of Rural Studies, Llanbadarn Campus, University of Wales, Aberystwyth SY23 3AL, UK

† E-mail : a.vanheelsum@ed.sac.ac.uk

‡ Present address : Department of Animal and Poultry Sciences (0306), Virginia Polytechnic Institute and State University, 3100 Litton-Reaves Hall, Blacksburg, Virginia 24061, USA.

Abstract

While crossing of specialized sire and dam breeds can be biologically efficient overall, a by-product is produced in the form of (crossbred) males of the dam line that are unwanted for breeding. In the UK sheep industry, most commercial females are first crosses between males of 'longwool' crossing sire breeds, predominantly the Bluefaced Leicester, and females of hill breeds. Genetic improvement of carcass quality in longwool breeds would benefit the surplus F₁ males as well as filter through to the terminal sire cross lambs produced by the F₁ ewes. As a first step, this paper aims to describe the growth and carcass characteristics of crossbred 'Mule' wether offspring of Bluefaced Leicester sires and Scottish Blackface and Hardy Speckled Face dams, and relate the crossbred performance to the 'lean' index and live conformation score of the sires and the breed of the dams. In each of 3 years, 1500 hill ewes divided over three sites were mated to 15 ram lambs, selected using an elliptical design to best represent the full spectrum of lean index (designed to improve muscle and decrease fat content while keeping live weight unchanged) and live conformation score present in the Penglis Bluefaced Leicester Group Breeding Scheme. Full growth and slaughter records were available on 2192 Mule wether lambs slaughtered after reaching finished condition, defined as the borderline between MLC fat class 2 and 3L. Measurements included live weight, ultrasonic muscle and fat depth, live conformation score, carcass hot and cold weight, MLC fat score (on the standard seven-point scale) and conformation score (EUROP and 15-point scale) and a visual estimation of subcutaneous fat cover. Nearly 800 carcasses were dissected; 20% had a full side and 80% a shoulder dissection. In part-dissected carcasses, shoulder dissection results were used to predict the fat and lean content of the other joints. Fat and lean percentages and absolute weights were then regressed on the lean index and the residual live conformation score of the sire. At the same finished condition, Scottish Blackface offspring were heavier, older, and had less fat and more lean based both on ultrasound and on carcass dissection measurements compared with Hardy Speckled Face offspring. The index score of the sire had a positive effect on the lean content and a negative effect on fat content of all joints. Conformation of the sire did not have a significant effect on any of the carcass composition measurements, but most conformation traits measured on the animal itself (live or on the carcass) were positively related to fat and negatively to lean content in the carcass. When taking into account differences in visually assessed subcutaneous fat percentage, the carcass conformation traits persisted only in having a positive effect on carcass fat content; none of the conformation traits had an effect on carcass lean content. The results show that selection of sires on lean index is an effective way to improve carcass composition in Mule wethers, but selection on conformation is ineffective.

Keywords: Bluefaced Leicester, carcass composition crossbred progeny, lambs.

Introduction

Sheep production in several countries relies on the use of crossbreeding, and the use of specialized sire and dam breeds. For example, in the UK, most commercial females are F_1 crosses between males of 'longwool' or crossing sire breeds, predominantly the Bluefaced Leicester, and females of hill breeds, like the Scottish Blackface, Swaledale and Hardy Speckled Face. This is part of a stratified crossbreeding system that integrates different systems of sheep production (with their specific breed types) which have evolved as an adaptation to the different climatic and topographical circumstances across the UK.

While the use of complementary breeds is biologically efficient overall (Dickerson, 1978; Smith, 1964), one of the less efficient components of such systems is the production of males from the dam breed or cross, unwanted for breeding. In principle, semen sexing could circumvent the production of these surplus animals, but this is unlikely to be cost-effective in sheep in the foreseeable future. However, improving the carcass quality of these ram lambs would improve the economics of the breeding programme.

In 1999, only 47% of all carcasses in the UK met the MLC target specifications for weight, fatness and conformation (Meat and Livestock Commission (MLC), 2000). The increasing emphasis on better and more consistent quality within the meat sector makes carcass leanness and conformation more important issues for sheep breeders. Genetic improvement of carcass quality in crossing sire breeds would benefit the crossbred wethers that form the by-product of the production of dam line ewes, and gains would also filter through to the terminal sire cross lambs produced by the crossbred ewes. It is therefore worth exploring the economically optimal selection objectives for crossing sire breeds, including meat production of the crossbred males, additional to their function as sires of F_1 ewes of superior reproductive competency.

First, information is needed on growth and carcass characteristics of the crossbred males and the maternal performance of the crossbred females in relation to the performance of the crossing sire breeds. This paper focuses on the crossbred wether lambs, relating their growth and carcass characteristics to the selection index (designed to improve muscle and decrease fat content while keeping live weight unchanged) and live conformation score of their sires and the breed of their dams. The Bluefaced Leicester represented the crossing sire breeds, being the most commonly used

crossing sire breed in the UK, and as dam breeds the Scottish Blackface (a relatively large-framed hill breed) and the Hardy Speckled Face (a relatively small-framed hill breed) were used.

Material and methods

Selection of crossing sires

The Bluefaced Leicester crossing sires were selected from approximately 800 ram lambs born each year between 1997 and 1999 in the 13 member flocks of the Penglas Bluefaced Leicester Group Breeding Scheme. Flocks were spread over Wales, Scotland and England and managed under diverse conditions. They were genetically linked by common use of reference sires and were subjected to comprehensive pedigree and performance recording. The crossing rams were selected to represent the full spectrum of index and live conformation scores as found in the sheep of the Penglas Scheme by applying an elliptical design with regard to their (unscaled) 'lean' index score and their residual (live) conformation score after correction for fixed effects. The lean index was designed to keep live weight at 150 days unchanged and to increase lean body mass while restricting increases in fat by placing a three times higher (positive) economic weight on lean weight than on fat weight (which was given a negative economic weight). The selection criteria used to achieve this goal were live weight, ultrasonic muscle and fat depth (at the third lumbar vertebra) measured at approximately 150 days of age when live gigot conformation was also assessed. Residual conformation scores were obtained by taking into account the fixed effects of year, flock, sex, age at measurement, age of rearing dam and (if applicable) foster-effect.

Cameron and Thompson (1986) showed that for the purpose of calculating genetic parameters, it is more efficient to select sires for two traits based on an ellipse value, rather than selecting two groups of sires, each one containing the most extreme individuals (equal proportions high and low) for one of the two traits of interest. The ellipse was given by the formula

$$w^2 = \frac{x_1^2 + x_2^2 - 2x_1x_2r_p}{1 - r_p^2}$$

where w was chosen such that a predetermined proportion of the individuals were outside the ellipse and were then chosen as potential crossing sires. In this formula, x_1 represents the unscaled lean index

score; x_2 represents the residual live conformation score; and r_p represents the correlation between x_1 and x_2 , which was re-estimated each year based on the actual values of the selection candidates (in 1997 : 0.18; in 1998 : 0.08 and in 1999 : 0.04).

Mating of the hill ewes

In each of three years (1998 to 2000), 1500 hill ewes (comprising equal numbers of Scottish Blackface and Hardy Speckled Face) lambed to 15 Bluefaced Leicester ram lambs. Approximately a third of the hill ewes was culled each year and replaced by younger ewes. Ewes were kept at three experimental farms near Aberystwyth in Wales: 500 at a farm at the sea front with free draining shallow soils, 600 at a farm in the Welsh foot hills and 700 at a hill farm situated 200 to 625 m above sea level with mainly rough grazing on poor stony soil. The Hardy Speckled Face (HSF) ewes were all sourced locally whereas the Scottish Blackface (SBF) ewes were sourced from the north of England and south-central Scotland. Ewes were allocated to sites balanced by breed, source, age and condition score, and to mating groups balanced by numbers at each site, age and condition score. Mating by artificial insemination with fresh semen took place over a 10-day period each year. Of the 4538 matings, 3334 resulted in a litter of crossbred 'Mule' (Bluefaced Leicester $\times$ hill breed) lambs; of the 5537 lambs born (including dead lambs), 4846 were reared up to at least 10 weeks of age. From 10 weeks of age, condition was assessed at two-weekly intervals until 'finished' condition was reached (equivalent to the borderline between fat class 2 and 3L). The male lambs, which were castrated at birth, were then slaughtered. The age of 'finish' varied widely between 74 and 300 days. Over the 3 years, 2255 wether lambs were slaughtered of which 2192 had complete records that were used in the analysis.

Performance recording on Mule lambs

Lambs were first weighed at birth, and subsequently at 5, 10 and 16 weeks of age and at finished condition. Detailed birth records were collected including birth type, dam and foster dam identification, birth date, sex, lambing difficulties and any abnormalities. The hill ewes were condition scored at lambing and weighed and condition scored when lambs were 5 weeks of age as well as pre-mating. At reaching finished condition, lambs were weighed, condition scored, their shoulder, loin and gigot conformation was assessed and they were ultrasound scanned to determine fat and muscle depth. Conformation was scored on a (subjective) scale of 1 (poor) to 6 (excellent). Ultrasonic muscle depth (UMD) was measured at the deepest point of the eye-muscle (*m. longissimus lumborum*) at the third

lumbar vertebra. Ultrasonic fat depth (UFD) was measured at the same position as well as 1 and 2 cm lateral to the first position. In the analysis the average of the three fat measurements was used.

Food was withheld overnight from lambs that went for slaughter to determine their 'empty' live weight. In the abattoir, the carcasses were weighed and classified for fatness and conformation using MLC standards, and given a (subjective) assessment of the subcutaneous fat percentage. Fatness was scored from 1 (low fat), 2, 3L, 3H, 4L, 4H to 5 (very fat) and conformation from E (excellent), U, R, O to P (poor). Additionally, the shoulder, loin, gigot and overall conformation was assessed on a 15-point scale. All abattoir assessments were carried out by the same person. After chilling overnight the cold carcass weights were recorded.

Of the 794 carcasses forwarded for dissection, 159 had a full side dissection (20%) and 635 had the shoulder joint dissected only. This percentage was determined by the double sampling technique applied to dissection work described by Conniffe and Moran (1972). They suggested the complete dissection of a subsample of the carcasses only and, for the remaining carcasses, the dissection of just a descriptive sample joint (e.g. a shoulder joint) to obtain 'concomitant' variables. The concomitant variables are then used to 'correct' the test statistic for treatment differences in the complete dissection data. This results in a more powerful comparison than when using the full side dissection data only, and is cheaper than fully dissecting all carcasses. Cook *et al.* (1983) used the approach to calculate the most cost-effective proportion of carcasses to undergo full side dissection. They gave the optimum proportion as:

$$\frac{\tan(\sin^{-1}[k^{1/2}])}{\tan(\sin^{-1}\rho)}$$

where k is the cost of the sample joint dissection as a proportion of the cost of side dissection, and ρ is the correlation between the variable measured on the sample joint and the same variable measured on the full side. They quote figures for $\rho = 0.90$ and $k = 0.16$ when the sample joint is the shoulder, resulting in an optimal proportion of carcasses to undergo full side dissection of 0.21.

On all dissected carcasses, many size and weight measurements were taken, as well as fat depth and muscle size measurements. The measurements used

Table 1 Description of analysed traits measured on live animals and carcasses, including number of observations (No.) used in the analysis

Abbreviation	No.	Description
Bwt	2194	Weight at birth (kg)
5wk_wt	2170	Weight at approximately 5 weeks of age (kg)
10wk_wt	2176	Weight at approximately 10 weeks of age (kg)
16wk_wt	1663	Weight at approximately 16 weeks of age (weaning) (kg)
UMD	2197	Ultrasonic muscle depth at 3rd lumbar position (mm)
UFD	2197	Ultrasonic fat depth at 3rd lumbar position (average of three measurements) (mm)
Finwt	2197	Live weight at reaching 'finished' condition (kg)
Confs/conf1/confg	2197	Live conformation score of the shoulder/loin/gigot (scale 1 to 6)
Finage	2193	Age at reaching 'finished' condition (days)
Emptylwt	2100	'Empty' live weight before slaughter (kg)
C15all	2195	Overall carcass conformation on 15-point scale
C15g/c15l/c15s	2195	Carcass conformation of the gigot/loin/shoulder on 15-point scale
Hotwt	2194	Hot carcass weight (kg)
Coldwt	2134	Cold carcass weight (kg)
Fatpc	2193	Estimated subcutaneous fat percentage
Killout	2040	Killing-out percentage (coldwt as part of emptylwt)
Eyelum	706	Eye muscle area at third lumbar vertebra (cm ²)
Eyerib	733	Eye muscle area at 12th rib (cm ²)
Butt	789	Circumference of buttock [mm]
A	790	Greatest width of <i>m. longissimus thoracis</i> at 12th rib (mm)
B	790	Greatest depth of <i>m. longissimus thoracis</i> at 12th rib (mm)
C	790	Subcutaneous fat depth immediately over B (mm)
Shl_ln/shl_fat	788†	Percentage or absolute weight (g) of lean/fat in shoulder joint

† On 158 of these carcasses, the percentage and the absolute weight (g) of lean and fat was also measured on the seven other joints (leg, chump, loin, breast, best end neck, middle neck, scrag).

in the analysis are described in Table 1. Fully dissected carcass sides were separated into eight joints (leg, chump, loin, breast, best end neck, middle neck, shoulder and scrag) as described by Cuthbertson *et al.* (1972). Joints (for 80% of the carcasses the shoulder joint only) were dissected into lean, fat (intermuscular and/or subcutaneous), bone (vertebral processes and/or other bone), and waste.

Statistical analysis

The variables listed in Table 1 were analysed using a regression model including a number of fixed effects: year (1998, 1999 or 2000), site (three farms), dam breed (SBF or HSF), birth-rearing type (6 classes), fostered or reared normally (artificially reared lambs were discarded) and age of the (rearing) dam (four classes: 1 or 2, 3, 4 to 6 or more than 6 years old). The combined birth-rearing type classes were: (1) born and reared as single; (2) born as twin, reared as single; (3) born as triplet, reared as single; (4) born as single, reared as twin; (5) born as twin, reared as twin; (6) born as triplet, reared as twin. The interaction between year and site was found to be of importance and was therefore also taken into account. For those measurements taken at a fixed point in time (i.e. 5-, 10- and 16-week weights) a covariate was included to adjust for differences in age of the lambs. For the finish and slaughter

measurements the covariate condition score was included to adjust for differences in degree of finish.

The variables were regressed on lean index and on residual conformation score of the sire. Both regressors were as described in the elliptical design section, except that the index for this application had been scaled to give a mean of 100 and a standard deviation of 25 units for the base animals (1997-born animals with valid scanning data). Scaled lean index values varied between -25 and 160 for the 45 sires used (with an average of 96). Fixed effects were estimated taking into account imbalance in the data, and predicted means were calculated weighting each fixed effect class according to the number of occurrences in the whole dataset, and using average values for the covariates (e.g. for finish and slaughter measurements an average age at finish (= 195 days) was used). When the lean index of the sire was fitted, predicted values were based on an index value of 100 (unless stated otherwise).

The EUROP-conformation and MLC-fat scores are both categorical traits with a relatively low number of classes, whereas the 15-point conformation scores and the percentage of subcutaneous fat assessment are both more closely resembling a continuous scale (although in essence these traits are categorical as

Table 2 Predicted values with standard errors for lamb live weights (kg) † up until weaning, comparing offspring of the two dam breeds (SBF = Scottish Blackface; HSF = Hardy Speckled Face) and of sires with a scaled lean index value of 50 or 150, and significance of dam breed effect and of lean index regression

	Dam breed					Lean index of sire‡			
	SBF	s.e.	HSF	s.e.	Significance	50	s.e.	150	s.e.
Bwt	4.4	0.02	4.2	0.02	***	4.3	0.02	4.3	0.03
5wk_wt	14.1	0.07	14.0	0.06		14.0	0.07	14.0	0.08
10wk_wt	22.6	0.10	22.1	0.09	***	22.3	0.11	22.3	0.11
16wk_wt	28.1	0.14	27.3	0.13	***	27.5	0.15	27.8	0.16

† Analysed traits are described in Table 1.

‡ Effect of lean index of sire was not significant at any of the ages ($P > 0.05$).

well, but with a larger number of classes). It was investigated if the more detailed traits are a refinement of the standard scores, or if they are measurements of different traits. Because correlations were found to be quite good, and continuous traits are better suited to this type of analysis, the more detailed traits only have been used in the regression analysis.

Combining data on shoulders and other joints

For the carcasses of which a full side was dissected, the correlation between measurements on the shoulder and on the seven other joints was investigated. A regression model was fitted to the lean and fat percentage (as part of total joint weight) and absolute weight measurements of the seven joints and the sum of all eight joints, regressing these on either lean or fat percentage/weight of the shoulder. Other factors included were year, site (and their interaction), birth-rearing type, age of rearing dam, and the covariates lean index of the sire, condition score at finish and age at finish. Subsequently, a very simple model was fitted, including the regression on percentage or weight of lean or fat in the shoulder only. The percentage of

variance accounted for by the full model was seldom more than five percent higher than for the simple model and none of the other variables was consistently of second-most importance. Hence, the simple model was chosen for estimation of predicted values for percentage and weight of lean and fat in the seven joints other than shoulder. Predicted values were scaled to have the same mean and standard deviation as the observed values. True and predicted values were then analysed using a weighted regression model, where the weighting was the accuracy of the measurement (for the observed values this was unity, and for the predicted values this was the correlation for that joint between observed and predicted values in fully dissected carcasses).

Besides the regressions on lean index and live conformation score of the sire, some additional models were fitted to lean and fat percentage of the sum of joints in order to investigate the effect of live animal and carcass conformation assessments. Fixed effects were as described above, but the sire's lean index or conformation score regressor was replaced by either live shoulder, loin or gigot conformation, or

Table 3 Predicted values with standard errors for measurements† on live lambs at finished condition, comparing offspring of the two dam breeds (SBF = Scottish Blackface; HSF = Hardy Speckled Face) and of sires with a scaled lean index value of 50 or 150, and significance of dam breed effect and of lean index regression

	Dam breed					Lean index of sire				
	SBF	s.e.	HSF	s.e.	Significance	50	s.e.	150	s.e.	Significance
Finwt (kg)	36.7	0.14	33.8	0.12	***	34.8	0.14	35.2	0.15	*
Finage (days)	196.3	1.8	178.3	1.6	***	184.9	1.8	187.1	1.9	
UMD (mm)	22.5	0.06	21.7	0.06	***	21.8	0.06	22.4	0.07	***
UFD (mm)	3.51	0.03	3.70	0.03	***	3.69	0.03	3.55	0.03	**
Confs	3.29	0.01	3.20	0.01	***	3.24	0.01	3.25	0.02	
Confl	3.43	0.01	3.39	0.01	*	3.40	0.01	3.41	0.01	
Confg	3.24	0.01	3.22	0.01		3.21	0.01	3.25	0.01	*

† Analysed traits are described in Table 1.

15-point shoulder, loin, gigot or overall carcass conformation. Additionally, estimated subcutaneous fat percentage was included in the model in order to improve the adjustment for differences in fatness.

Results

For most variables, the fixed effects of dam breed, year of birth, site and interaction between year and site were very important. Table 2 shows the significance of the dam breed effect and the regression on sire's index value, with regard to weights of lambs up until weaning. As an example, Table 2 also shows the predicted means for lambs from the two dam breeds and for lambs with sires with a lean index (scaled to an average of 100 and a standard deviation of 25 for base animals) of 50 compared with 150. Lambs from SBF dams were generally heavier than lambs from HSF dams, in line with the size difference between the dam breeds. A difference of 100 index points resulted in only very little change in lamb live weight, as would be expected from an index that aims to keep live weight at 150 days unchanged. Lambs were on average heaviest in 2000 compared with the earlier years, but this was not consistent over all sites (results not shown).

The age at which lambs reached finished condition varied greatly (Figure 1). The pattern changed somewhat over the years, but generally there was an early rush of predominantly single lambs that

finished in the summer months, followed by a slump caused by weaning, and particularly in the first two years a substantial rise only occurred after supplementary feeding was introduced (close to November). In 2000 however, a sizeable number of lambs was slaughtered in September and October. In all three years, the last lambs did not finish until well into January of the following year.

For the traits measured at finished condition, the differences between lambs from the two dam breeds were often significant and sometimes substantial (Table 3). Predicted values were adjusted to the same condition score, used as a measure of the degree of finish. The SBF offspring took longer to reach finished condition, but were then heavier with a greater ultrasonic muscle depth and smaller ultrasonic fat depth than the HSF offspring. The effect of the sire index value was significant for live weight at finish and both muscle (positive) and fat depth (negative), suggesting that offspring of high-index rams were taken to a higher weight without becoming over-fat and while putting on more muscle.

Further support for this suggestion was found in the results from the analysis of slaughter and dissection data (Table 4). Offspring of high-index rams scored on average slightly better for the traits related to muscularity, whereas their fat measurements were slightly lower. This was particularly apparent in the dissected lean and fat content of the shoulder joint.

Table 4 Predicted values with standard errors for slaughter and dissection measurements† on offspring of the two dam breeds (SBF = Scottish Blackface; HSF = Hardy Speckled Face), and of sires with a scaled lean index value of 50 or 150, and significance of dam breed effect and of lean index regression

	Dam breed					Lean index of sire				
	SBF	s.e.	HSF	s.e.	Significance	50	s.e.	150	s.e.	Significance
Emptywt (kg)	34.6	0.13	31.9	0.12	***	32.8	0.13	33.3	0.14	**
Hotwt (kg)	16.7	0.06	15.8	0.05	***	16.1	0.06	16.2	0.07	
Coldwt (kg)	16.3	0.06	15.4	0.05	***	15.7	0.06	15.8	0.06	
Killout (%)	47.0	0.11	48.3	0.09	***	47.9	0.11	47.6	0.11	
Fatpc (%)	11.0	0.05	11.2	0.04	**	11.2	0.05	11.0	0.05	*
C15all	6.6	0.04	6.3	0.04	***	6.4	0.04	6.5	0.04	
Eyelum (cm ²)	12.2	0.08	11.6	0.08	***	11.8	0.08	12.1	0.09	*
Eyerib (cm ²)	11.0	0.07	10.5	0.07	***	10.6	0.07	10.9	0.08	*
Butt (mm)	598.5	1.1	587.5	1.1	***	590.6	1.2	595.4	1.3	**
A (mm)	56.9	0.16	56.4	0.17	*	56.3	0.17	57.0	0.19	**
B (mm)	25.8	0.12	25.0	0.12	***	25.1	0.12	25.7	0.13	**
C (mm)	2.9	0.06	3.1	0.06		3.2	0.07	2.8	0.07	**
Percentage of lean/fat as part of total weight of shoulder joint										
Shl_ln	59.9	0.13	58.6	0.13	***	58.6	0.14	60.0	0.15	***
Shl_fat	22.5	0.16	23.8	0.16	***	24.0	0.17	22.3	0.19	***
Absolute weight of lean/fat in shoulder joint (g)										
Shl_ln	962.5	5.1	918.2	5.2	***	926.3	5.4	954.5	5.9	**
Shl_fat	360.5	3.6	381.2	3.6	***	383.0	3.8	358.6	4.1	***

† Analysed traits are described in Table 1.

Table 5 Correspondence between EUROP and 15-point carcass conformation score for 2238 Mule wether lambs classified at slaughter

	U	R	O	P	Total
C15all 1				1	1
2				6	6
3			8	4	12
4			66	17	83
5		1	368	2	371
6		26	719		745
7		178	415		593
8		257	47		304
9	1	99	2		102
10	9	9	1		19
11	2				2
Total	12	570	1626	30	2238
Mean	10.1	7.8	6.0	3.4	6.4

The same trends as observed in the finish traits persisted in the slaughter traits as far as dam breed effects were concerned. Again, the SBF offspring were heavier and scored higher for muscle measurements and lower for fat measurements than HSF offspring. Carcasses were heaviest in 2000 and had the largest absolute lean and fat quantities. This

increase in shoulder size was associated with a relatively larger increase in fat than in lean levels; although the percentage of fat in the shoulder was highest of the three years in 2000, the percentage of lean was lowest in that year (data not shown).

None of the finish or slaughter traits gave a significant regression on residual conformation score of the sire, except finwt and emptywt (-0.4 ± 0.1 kg), age at finish/slaughter (-4.5 ± 1.2 days) ($P < 0.001$ for all four traits), hot carcass weight (-0.12 ± 0.04 kg; $P < 0.01$), cold carcass weight (-0.10 ± 0.04 kg) and killing-out percentage ($0.17 \pm 0.07\%$) (both $P < 0.05$). Hence, the offspring of high-conformation sires reached finished condition more quickly and at a lower weight with a slightly better killing-out percentage than offspring of low-conformation sires. Interestingly, none of the conformation traits on the live animal or on the carcass gave a significant regression on residual conformation score of the sire.

The standard MLC conformation assessment on the EUROP scale (where 'E' is excellent and 'P' is poor) corresponded well with the 15-point conformation score (Table 5). Carcasses assessed as 'U' were mainly given an overall 15-point conformation score of 10, 'R' corresponded with 8 (with 94% of 'R's classified between 7 and 9), 'O' corresponded with 6 (92% of

Figure 1 Percentage of mule wethers reaching finished condition per fortnight.

Table 6 Correspondence between MLC fat class on a scale from 1 (low fat), 2, 3L, 3H, 4L, 4H to 5 (very fat) and visual estimation of subcutaneous fat percentage (fatpc) classified according to ranges found by Kempster *et al.* (1986), for 2209 Mule wether lambs graded at slaughter

Fat class	1	2	3L	3H	4L	4H	5	Total
Fatpc < 6	12	3					15	
6-9	17	134	45	1				197
10-11	1	384	585	3				973
12-13			738	174				912
14-15				85	23			108
16-17					2	1		3
18-19							1	1
Total	30	521	1368	263	25	1	1	2209
Observed mean	5.8	9.5	11.4	13.3	15.1	17.0	19.0	11.1
Expected mean†	4.0	8.0	11.0	13.0	15.0	17.0	20.0	
Observed range	2-10	4-11	6-12	7-14	15-16	17	19	

'O's classified between 5 and 7) and 'P' with 4 or lower. The correspondence between MLC fat class (on the scale of 1, 2, 3L, 3H, 4L, 4H, 5) and subcutaneous fat percentage assessment was more ambiguous (Table 6). The agreement with the expected mean fat percentages according to Kempster *et al.* (1986) is sometimes poor, particularly at the lower end of the scale, and the range of fat percentages is much larger (mainly in the lower direction) than suggested by the aforementioned authors.

The MLC generally considers carcasses classified for conformation as 'R' or better and in fat class 3L or lower as acceptable (MLC, 2000). Based on conformation only, just 26% of the crossbred lambs met the target, and based on fat score alone, 87%.

Table 7 Correlation between composition of shoulder and composition of other joints, for lean and fat expressed as percentage of total joint weight or as absolute weight of joint, based on 158 Mule wether carcasses that underwent full side dissection

	Lean in joint		Fat in joint	
	Percentage	Absolute weight	Percentage	Absolute weight
Leg	0.55	0.91	0.72	0.86
Chump	0.68	0.80	0.80	0.83
Loin	0.65	0.80	0.83	0.85
Breast	0.71	0.78	0.74	0.82
Best end neck	0.77	0.89	0.88	0.90
Middle neck	0.33	0.94	0.53	0.64
Scrag	0.21	0.72	0.60	0.59
Sum of joints	0.85	0.97	0.92	0.95

Taking the two scores together, just 22% were acceptable.

Ultimately, the true value of a carcass lies in the amount of lean and fat it contains. The amount of lean and fat in joints other than the shoulder for those carcasses on which no full side dissection results were available, was predicted from the shoulder composition. Table 7 shows that for the percentage measurements, the correlations between shoulder and other joints was always lower for lean content than for fat content, whereas for the absolute measurements the reverse also occurred. The lowest correlations for the percentage measurements were found for scrag and middle neck, whereas the highest correlations were found for best end neck, and breast, chump and loin. The correlations found for the absolute weight measurements were generally higher, as a result of the strong effect of overall body size on the weights of lean and fat in each joint.

It was found that the lean index value of the sire (based on objective measurements of live weight, fat and muscle depth) consistently had a significant effect on the percentages as well as the absolute weights of lean and fat in all joints of the carcass (Table 8). For the lean percentages and absolute weights the regression on lean index was always positive and for fat percentages and weight always negative. The regression on residual conformation of the sire was significant only for percentage of lean in the middle neck; the regression coefficient was -0.24 (s.e. 0.11; $P < 0.05$). None of the regressions on residual conformation was significant ($P > 0.05$) for the absolute weight measurements.

Table 8 Predicted means with standard errors for joint composition (lean and fat content expressed as percentage of total joint weight or as absolute weight) and regression coefficients (*b*) of joint composition on sire's lean index value (values for shoulder are based on 788 Mule wether carcasses of which the shoulder was dissected; values for other joints based on 158 full side dissections and 630 predicted values through their correlation with shoulder values)

	Percentage of joint weight				Absolute weight (g)			
	Predicted mean	s.e.	<i>b</i>	s.e.†	Predicted mean	s.e.	<i>b</i>	s.e.§
Lean in joint								
Shouldert	59.3	0.1	0.014	0.002	940	4	0.28	0.09
Leg	66.3	0.1	0.009	0.001	1271	5	0.35	0.11
Chump	59.9	0.1	0.016	0.003	365	2	0.12	0.04
Loin	62.1	0.1	0.024	0.003	491	2	0.13	0.05
Breast	49.3	0.1	0.021	0.003	380	2	0.14	0.05
Best end neck	52.3	0.1	0.021	0.003	300	1	0.09	0.03
Middle neck	61.9	0.1	0.012	0.002	571	2	0.16	0.06
Scrag	52.8	0.1	0.017	0.003	113	1	0.04	0.01
Sum of joints	59.9	0.1	0.013	0.002	4421	16	1.25	0.40
Fat in joint								
Shouldert	23.1	0.1	-0.017	0.003	371	3	-0.24	0.06
Leg	14.4	0.1	-0.010	0.002	277	2	-0.17	0.04
Chump	23.3	0.1	-0.020	0.003	144	1	-0.12	0.03
Loin	21.5	0.2	-0.026	0.004	175	2	-0.20	0.04
Breast	32.4	0.2	-0.025	0.004	254	2	-0.21	0.05
Best end neck	27.6	0.2	-0.028	0.004	163	1	-0.16	0.04
Middle neck	15.1	0.1	-0.012	0.002	141	1	-0.10	0.03
Scrag	15.2	0.1	-0.020	0.003	33	0.4	-0.04	0.01
Sum of joints	20.9	0.1	-0.016	0.002	1561	11	-1.16	0.27

† Based on direct observations only.

‡ $P < 0.001$ for all joints.

§ $P < 0.001$ for all fat weights; all lean weights $P < 0.01$ except for scrag ($P < 0.05$).

Although the (live) conformation score of the sire did not have a significant effect on the dissected amounts of lean and fat in the carcasses of the crossbred offspring, many of the conformation scores of the lambs themselves were correlated with their own carcass lean and fat content. Live conformation of the gigot and loin did not influence the percentage of dissected lean and fat in the carcass (sum of joints), but live conformation of the shoulder affected the lean percentage negatively ($P < 0.05$) and fat percentage positively ($P < 0.01$). If the estimated percentage of subcutaneous fat was fitted in the model as well, the importance of live shoulder conformation diminished, although it was still significant for fat percentage ($P < 0.05$). The 15-point carcass conformation scores generally had a large negative effect on percentage of lean and a large positive effect on fat percentage in the carcass ($P < 0.001$) but after including estimated subcutaneous fat percentage in the model the effect on dissected carcass lean was lost ($P > 0.05$). However, the effect on total carcass fat generally persisted, most significantly so for c15s ($P < 0.001$) but also for c15l and c15all ($P < 0.01$).

Discussion

The carcass fat and conformation scores as assessed in the abattoir clearly show the need for improvement of carcass quality of Mule lambs. It is therefore very encouraging to see that the carcasses of offspring of high lean index sires contained more lean and less fat. The live conformation of the sire was shown to be of negligible importance to lean and fat content of the carcasses of their offspring, although the effect on fatness could be (partially) obscured by lambs being slaughtered at the same level of 'finish' (i.e. fat cover). The results suggest that selection on conformation will not improve muscle quantity, whereas the effect on fatness is somewhat unclear.

Several authors have studied the value of conformation as an indicator of carcass composition. Kempster *et al.* (1981) summarized work carried out in the mid 1960s by concluding that lamb carcasses with good conformation tend to be fatter than poorer conformation carcasses and have little advantage in muscle thickness. Their own work confirmed that carcass conformation is a poor indicator of carcass

lean content, in particular when differences in fatness are not properly accounted for. More recently, Lewis *et al.* (1996) also found a positive link between the visual appraisals of carcass fat and conformation in crossbred (Suffolk $\times$ Scottish Mule) lambs slaughtered at a constant weight. These results agree with our observation that conformation is positively correlated with carcass fatness. Once fatness is accounted for, conformation has no predictive value for carcass lean percentage. Jones *et al.* (1999), using the same data as Lewis *et al.* (1996), showed that genetic correlations between all considered conformation scores and tissue proportions were not significantly different from zero and therefore of little to no value in predicting carcass composition. Our results agree by suggesting a positive (phenotypic) correlation between conformation and carcass fat percentage, but making a significant genetic correlation look unlikely given the lack of a significant effect of sire's conformation score on carcass fat. Van Heelsum *et al.* (2001) however found a positive genetic correlation between live conformation score and ultrasonic fat and muscle depth in Bluefaced Leicester sheep at 21 weeks of age. Although the latter two are not direct measures of carcass composition, they would be expected to be related to carcass lean and fat content. Also, our data involved crossbred animals of similar fatness (finished condition) and not pure-breds of similar age, and any differences in finished condition still present would have been taken out by including condition score in the model for finish and slaughter traits. Hence, if fatness and conformation were indeed closely related, differences in conformation would be expected to be small. To draw any firmer conclusions, a further genetic analysis including all pedigree information would be needed. In the mean time, the value of subjective conformation assessments to a breeding scheme aiming at improving carcass composition remains doubtful.

Commercial lambs do not typically get a 15-point conformation score or an assessment of percentage of subcutaneous fat, but are often assessed for fatness on a seven-point scale (1, 2, 3L, 3H, 4L, 4H and 5) and for conformation on a five-point scale (EUROP). Given the fairly small number of classes, neither of the common fat and conformation scores should be assumed to follow a normal distribution. This study suggests that the overall conformation score on a 15-point scale is a straightforward refinement of the EUROP score, with median 15-point scores central within EUROP class and differing by at least two points from each neighbouring EUROP class. The advantages of the 15-point scale are that the scale is nearer continuous, and it more strongly suggests equal measurement units across the scale. However,

on either scale the trait measured is still subjective, and unless it can be more clearly defined by means of objective measurements, genetic improvement of conformation will be difficult.

The agreement between the seven classes of the standard MLC fat scoring scale and the subcutaneous fat percentage assessment was not as strong as reported by Kempster *et al.* (1986) and particularly the range was much larger. As with conformation, both scales were based on subjective assessments made by the carcass grader rather than on objective measurements. When comparing the MLC fat scores with the actual subcutaneous fat levels found by dissection of full sides, the agreement was reasonable for the classes with many observations but poor for the extreme ends of the scale: averages here were 8% (fat class 1), 8% (fat class 2), 10% (3L), 13% (3H) and 14% (4L).

The regression coefficients for regressing lean and fat content on the 'lean' index of the sire were quite variable between the different joints. For lean percentage, the largest coefficient was found in the loin joint, which also had one of the largest coefficients for fat percentage. Given that ultrasonic fat and muscle depth, the selection criteria used for the lean index, were measured at the third lumbar vertebra, this might not be surprising, because it merely implies that the highest response to selection was found in the joint on which selection has taken place. It does, however, pose the question if this could lead to an unequal increase in the amount of muscle tissue and decrease in fat tissue between joints, so changing the balance between the joints, although this seems unlikely. The current data are insufficient to draw any strong conclusions about this.

This data set provides a detailed progeny test of Bluefaced Leicester sires for crossbred performance related to carcass traits. This particular breed type has not been studied much before, although the study of Kempster *et al.* (1981) includes Border Leicester (as one of 10 sire breeds) $\times$ Scottish Blackface (as one of three dam breeds) crosses. The results on Border Leicester offspring (pooled over dam breeds) show higher carcass weights and 15-point conformation scores, but a slightly lower percentage of lean in the carcass than found in our study. Results of a related breed type, consisting of a cross between terminal sires and first cross ewes, are more plentiful. For example, Lewis *et al.* (1996) and Simm and Murphy (1996) studied lambs produced by Suffolk sires out of Scottish Mule dams. In the latter two studies lambs were taken to a fixed weight rather than a fixed level of 'finish', further

complicating the comparison. Generally, the lambs in our study were lighter, leaner and less well conformed than the terminal sire cross lambs of the other studies. In comparison with Scottish Blackface lambs, used in a study by Conington *et al.* (1998), lambs in our study were also slightly lighter, but much younger and at a comparable level of 'finish' when being slaughtered (the finish criterion for these lambs was not weight but fat cover). The Scottish Blackface lambs had a somewhat lower proportion of lean and higher proportion of fat in the carcass.

In conclusion, the results show that by using high-index rams the leanness of the carcass of their crossbred offspring can be improved, without affecting live or carcass conformation and with only a small increase in size. The latter is of great importance to crossbred dam line sheep, because the goal to keep the size of crossbred ewes unchanged is considered important to overall efficiency. High-conformation rams gave slightly quicker finishing lambs with larger fat depths, but live and carcass conformation did not improve. This implies that selection on lean index will improve carcass quality, but the benefit of selection on live conformation remains unclear.

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