

# Effect of breed and castration on production and carcass traits of male lambs following an intensive finishing period

Noel A. Claffey,<sup>†,‡</sup> Alan G. Fahey,<sup>‡</sup> Vasiliki Gkarane,<sup>‡</sup> Aidan P. Moloney,<sup>§</sup>  
Frank J. Monahan,<sup>‡</sup> and Michael G. Diskin<sup>†,1</sup>

<sup>†</sup>Teagasc, Animal & Grassland Research and Innovation Centre, Mellows Campus, Athenry, Co. Galway, Ireland;

<sup>‡</sup>University College Dublin, School of Agriculture and Food Science, Dublin 4, Ireland; and <sup>§</sup>Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co. Meath, Ireland

**ABSTRACT:** The practice of crossbreeding using a terminal sire and the use of intact rather than castrated animals has the potential to increase the productivity of lambs produced from the hill sheep sector. The objective of this study was to compare the production and carcass characteristics of pure-bred Scottish Blackface (SB) and Texel cross Scottish Blackface (TXSB) ram and wether lambs fed on a concentrate diet and slaughtered at different ages. Two hundred spring born male lambs (average birth age  $\pm$  SD 9.53 d) were assigned to a 2  $\times$  2 factorial arrangement with two breeds SB ( $n = 100$ ) and TXSB ( $n = 100$ ) and two sexes (wether:  $n = 100$  and ram:  $n = 100$ ). Lambs were harvested following a 36 d ad libitum concentrate indoor finishing period. The study was carried out over five harvest batches between October and April. The mean ages of the lambs at harvest ( $n = 40$ ; 20 TXSB and 20 SB lambs) in October, November, January, March, and April were 196, 242, 293, 344, and 385 days, respectively. The TXSB lambs were heavier at slaughter than SB lambs ( $P < 0.001$ ), and ram lambs were heavier at slaughter than wether lambs ( $P < 0.01$ ). Improved

ADG ( $P < 0.001$ ), lower feed conversion ratio (FCR) (which was calculated by dividing total feed intake by total weight gain;  $P < 0.001$ ), and higher feed intake ( $P < 0.05$ ) were recorded in TXSB lambs with consistency across the five harvest time points. Rams had greater ADG ( $P < 0.001$ ) and FCR ( $P < 0.05$ ) compared with wether lambs, and no differences were observed between sexes for feed intake. The TXSB ( $P < 0.001$ ) lambs had higher ( $P < 0.001$ ) dressing percentages compared with SB, while wether lambs had greater dressing percentages compared with rams. The TXSB lambs had heavier carcass weights ( $P < 0.001$ ) with higher conformation grades ( $P < 0.001$ ) and less fat cover ( $P < 0.001$ ) than SB lambs, while ram lambs had heavier ( $P < 0.001$ ) carcasses than wether lambs. There was greater fat cover on the loin muscles of SB ( $P < 0.001$ ) and wether ( $P < 0.001$ ) lambs compared with TXSB and ram lambs, respectively. The results from this study suggest that TXSB lamb's offer hill sheep farmers a potential strategy for improved lamb production efficiency, while ram lambs offer lamb finishers increased growth rates, higher FCR, and produce a more desirable carcass than do wether lambs.

**Key words:** carcass, castration, cross-breeding, lamb, performance

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<sup>1</sup>Corresponding author: [Michael.diskin@teagasc.ie](mailto:Michael.diskin@teagasc.ie)

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## INTRODUCTION

Scottish Blackface (SB) ewes account for approximately 29% of the 2.64 million national

ewe breeding flock in Ireland and are predominantly maintained on hill and marginal land unsuitable for more intensive livestock farming systems (DAFM, 2016). The SB breed traditionally produced light carcasses (10–15 kg) which were exported to Mediterranean markets, but these markets are in decline. Consequently, hill sheep producers have begun to breed an increasing proportion of their SB ewes to maternal and terminal breed sires such as Texel (TX) to produce Texel cross Scottish Blackface (TXSB) lambs. The TXSB lambs, as a result of their added terminal genes compared with SB lambs, are expected to have greater growth rates, better conformation, and higher carcass weight, thus meeting greater market specifications than the traditional light lamb which were exported to the Mediterranean markets. In Ireland, approximately, 75% of male lambs from hill production systems are offered for sale either as store lambs for further finishing or for harvest between August and December each year. Grass is the predominant forage source in Irish livestock production (Finneran et al., 2010). However, grass supply diminishes as the grass-growing year progresses, so meeting the nutrient requirements of grazing lambs requires concentrate supplementation. Offering concentrates ad libitum to finishing lambs result in higher levels of lamb performance, though prolonged periods of concentrate feeding, which may be necessary for light hill lambs that lead to increased production costs (Keady and Hanrahan, 2015). To offset some of these production costs, ram lambs are favored over wether lambs given their increased feed efficiency, live weight gain, and production of leaner carcasses (Notter et al., 1991; Vergara et al., 1999; Keady and Hanrahan, 2015). Male lambs are commonly castrated to reduce sexual behavior and improve ease of management (Dransfield et al., 1990). Welfare issues have been raised around castration with castration of lambs now banned in Norway (Lind et al., 2011). There is little knowledge of the comparative performance and carcass characteristics of wether and ram lambs from pure breed SB and of TXSB genotypes. The objective of this study was to compare the production performance and carcass characteristics of purebred SB and crossbred TXSB ram and wether lambs fed on an intensive all-concentrate diet for a 36-d period prior to slaughter when slaughtered at different ages.

## MATERIALS AND METHODS

All animal procedures used in this study were conducted under experimental license from the Health Products Regulatory Authority (HPRA) in

accordance with the European Union protection of animals used for scientific purposes regulations 2012 (S.I. No. 543 of 2012).

### *Prestudy Management*

The study was undertaken at the Teagasc Sheep Research Centre, Mellows Campus Athenry, Co. Galway, Ireland. A total of 200 spring born male lambs were assigned to a  $2 \times 2$  factorial arrangement with two breeds (SB ( $n = 100$ ) and TXSB ( $n = 100$ )) and two sexes (wether [ $n = 100$ ] and ram [ $n = 100$ ]). The study was replicated over five periods between October 2014 and April 2015 (Table 1). The mean ages of the lambs at slaughter in October, November, January, March, and April were 196, 242, 293, 344, and 385 d, respectively. Lambs were identified at birth on six commercial source farms (Table 2), and a weight was recorded for each lamb within 1 h of birth. Each alternate male lamb born alive was castrated using a scrotal rubber ring within 48 h of birth (Molony et al., 2002). At 5 mo of age, lambs were weighed and inspected visually to confirm sex and disease-free status before being transported to the Teagasc Research Centre. On arrival at the Research Centre, lambs completed a routine bio-security protocol and were treated for internal and external parasites. A total of 240 lambs were initially sourced and brought to the research centre. Four farms produced SB lambs and three farms produced TXSB lambs. On each farm, five rams of each breed were used (Table 2). Prior to weaning, lambs were reared initially on in-bye land (low green land and land-grazing pasture), and at about 1 mo of age, lambs were on mountain grazing until weaning and transfer to the Research Centre. Following completion of the bio-security protocol, lambs were placed on grass pasture until selected for commencement of the indoor intensive finishing period. Within breed and sex, the 10 heaviest lambs were selected for the finishing period for each of the five slaughter time points. This randomized complete block design was favored over a completely random design to ensure similar starting weights across each time point. This method is also reflective of commercial practice. The distribution of age within each treatment is presented in Table 1 showing that the minimum age in a given month of slaughter was greater than the maximum age in the previous month, thus allowing month of slaughter to be used a factor in the analysis.

### *Finishing Period*

Lambs were individually penned on expanded metal floored feeding pens (182 cm L  $\times$  122 cm W)

**Table 1.** Minimum and maximum age of SB and TXSB lambs across months of slaughter

Breed & Sex	Month of slaughter	N	Minimum (d)	Maximum (d)	Mean (d)	SD (d)
SB ram	October	9	162	201	182	11.0
	November	10	222	245	232	9.0
	January	10	258	293	276	10.0
	March	10	320	368	340	14.0
	April	8	371	392	384	7.0
SB wether	October	10	177	201	191	6.0
	November	10	212	239	230	8.0
	January	10	254	293	277	10.0
	March	10	314	351	331	12.0
	April	10	368	401	384	9.0
TXSB ram	October	10	185	209	196	8.0
	November	10	228	258	251	8.0
	January	10	263	299	285	11.0
	March	10	337	359	352	7.0
	April	10	372	401	391	10.0
TXSB wether	October	10	191	223	209	12.0
	November	10	243	271	258	9.0
	January	10	286	315	305	7.0
	March	10	341	363	354	8.0
	April	10	372	401	391	10.0

**Table 2.** Contribution of the number SB and TXSB from each source farm

Farm	No. of SB lambs	No. of SB rams used	No. of TXSB lambs	No. of TX rams used
Farm 1	29	5	0	5
Farm 2	9	5	15	5
Farm 3	46	5	0	0
Farm 4	15	5	0	0
Farm 5	0	0	32	5
Farm 6	0	0	53	5
Total	100	20	100	20

for the 36-d indoor finishing period. During the finishing period, lambs were allowed tactile, olfactory, and visual contact with each other through the pen partitions. Lambs were allowed a 12-d pre-experimental acclimatization period to adapt to a 95% concentrate diet. Relative to commencement of ad libitum, concentrate feeding (day 0), lambs were offered 150-g/d fresh weight of concentrate feed on days -12, -11, and -10 increasing by 100-g/d fresh weight concentrate on each day from days -9 to d -1 to minimize the risk of any digestive upsets. For the duration of the finishing period, lambs were offered 100-g/d DM of silage and had ad libitum access to concentrates; ad libitum concentrate was described as access to concentrate feed at all times over the 36-d experimental period. Concentrate and silage samples were collected weekly and dried overnight at 55 °C and pooled for determination of CP, ADF, NDF, and ash. Concentrate and silage

were offered daily with individual lamb refusals recorded twice weekly. The concentrate used was a 60% cereal-based lamb ration with 15% CP and an energy value of 1-UFL/kg fresh weight (Table 3).

### Animal Measurements

On day 0 (start of 36-d intensive feeding period) lambs were weighed (without food or water restriction) and ultrasonically scanned (Dynamic Imaging, Livingston, UK) for muscle depth and fat thickness as described by Davis (2010). Muscle depth was measured as the deepest point of the eye muscle on the third lumbar vertebra; subcutaneous back fat thickness was measured directly above the eye muscle at this point, and lambs were ultrasonically scanned again on day 36. BW was also recorded at 7-d intervals.

Production variables measured included feed intake which was described as the amount of fresh weight (kg) concentrate the lambs consumed. These intakes were also used to calculate daily feed intake and feed conversion ratio (FCR), by dividing total feed intake by total weight gain. ADG was calculated by dividing total weight gain over the finishing period divided by the duration of the period.

### Post Slaughter

Lambs were transported to the slaughter facility on the morning of slaughter; each alternative lamb slaughtered was a different breed and sex to the

**Table 3.** Ingredient and chemical composition of concentrate and silage fed to TXSB and SB ram and wether lambs during the intensive finishing period

Concentrate		Silage
Ingredient (kg/tonne)		
Maize	300	—
Barley	300	—
Soya hulls	165	—
Soya bean meal	155	—
Molasses	50	—
Minerals	30	—
Chemical Composition		
DM, g/kg	850	230
Composition of DM, g/kg		
CP	150	176
NDF	620	267
ADF	337	141
Ash	73	61

previous lamb, ensuring equal waiting time before slaughter for each breed and sex. A captive bolt pistol was used to stun each lamb (Grandin, 1994). Immediately after stunning, lambs were exsanguinated, eviscerated and the skin and fleece removed. Cold carcass weight was recorded 24 h after harvest and used to calculate dressing percentage, as dressed carcass weight divided by preslaughter live weight multiplied by 100.

Carcasses were graded for conformation using the EUROP scale (Commission Regulation (EC) No 22/2008) which was coded 5, 4, 3, 2, and 1, respectively, for data analysis, and classified for fat cover using a 1 to 15 scale (1 = low fat cover, 15 = excess fat tissue), by the same operator.

### Data Analysis

Data residuals were examined for normality using the UNIVARIATE procedure of SAS (version 9.4, SAS Inst Inc., Cary, NC). Production and carcass data as well as summary statistic were analyzed and generated using the MIXED procedure of SAS (v 9.4). The model included fixed effects of source farm, breed, sex, and slaughter period as well as all appropriate interactions with lamb considered as the random effect. Relevant covariates such as weight at onset of intensive feeding period were used for production variables ADG, FCR, and intake, while for carcass traits, such as carcass conformation score, fat grade, and ultrasonic measurements, carcass weight was included as a covariate. Covariates remained in the model when significant effects were recorded and removed if not. For repeated measures analysis (ADG and

intake), the covariate structure yielding the lowest BIC value was chosen. All data presented in the tables were expressed as least squares means  $\pm$  SEM. The probability value, which denotes statistical significance, was  $P < 0.05$ . Stepwise forward linear regression (PROC REG) analysis was used to explore the relationships between selected production dependent traits (ADG, daily feed intake [fresh-weight basis]), FCR and dressing percentage. As well as independent variables and carcass dependent traits (carcass weight, carcass conformation, carcass fat score, ultrasonic fat depth over loin, and ultrasonic eye muscle depth), lamb breed was fitted as 0 (SB) and 1 (TXSB) with sex also fitted as 0 (wether) and 1 (ram). Values for SLentry and SLstay (version 9.4, SAS Inst Inc.) were both set at  $P = 0.15$ . Variables that contributed most to the explained variation were fitted first followed by other variables that improved the model (forward selection). Multicollinearity among independent variables was assessed using a variance inflation factor (VIF) statistic (Kaps and Lamberson, 2017). No parameters exceeded VIF values of three; therefore, all independent variables remained as candidate variables for selection in the model.

## RESULTS

There were no statistically significant interactions observed for any dependent variable, and therefore, only main effects are reported. Production and carcass traits for breed and sex are shown in Table 4.

### Breed

The TXSB lambs had greater starting weight ( $P < 0.001$ ), slaughter weight ( $P < 0.001$ ), total gain ( $P < 0.001$ ), ADG ( $P < 0.001$ ), daily intake 0–14 d ( $P < 0.001$ ), and daily intake 15–36 d ( $P < 0.001$ ) compared with SB lambs. The TXSB lambs had a lower FCR ( $P < 0.001$ ). For carcass traits, TXSB lambs had superior dressing percentage ( $P < 0.001$ ), carcass conformation score ( $P < 0.001$ ), ultrasound muscle depth ( $P < 0.001$ ), and ultrasound muscle gain (difference between ultrasound measurement on 0 and 36 d;  $P < 0.001$ ) compared with SB lambs. The SB lambs had higher carcass fat score ( $P < 0.001$ ) and fat depth ( $P < 0.001$ ). There was no difference in ultrasonic fat ( $P > 0.05$ ) and ultrasound fat gain ( $P > 0.05$ ), the later defined as the difference the between ultrasound fat measured on days 0 and 36 of the experiment. The summary statistics are presented in Tables 5 and 6 for the two



**Table 4.** Least squares means for production and carcass traits for SB and TXSB rams and wethers including SEM

P value	Breed			P value	Sex			P value
	SB	TXSB	SEM		Ram	Wether	SEM	
Production traits								
Start weight, kg	36.9	41.2	0.26	<0.001	39.1	39.0	0.25	0.929
Slaughter weight, kg	45.7	53.7	0.41	<0.001	50.5	48.9	0.41	<0.01
ADG, g/d	241	349	7.0	<0.001	314	272	7.0	<0.001
Total intake, kg*	53.7	59.4	0.79	<0.05	57.1	55.9	0.66	0.324
ADG days 0–14, g/d	261	379	16.0	<0.001	324	316	14.0	0.417
ADG days 15–36, g/d	236	316	11.0	<0.001	308	244	9.0	<0.001
Daily intake day 0–14, kg/d	1.44	1.61	0.021	<0.001	1.52	1.53	0.022	0.414
Daily intake day 15–36, kg/d	1.53	1.66	0.022	<0.001	1.62	1.52	0.010	<0.10
FCR <sup>†</sup> , kg	6.74	5.17	0.201	<0.001	5.58	6.31	0.200	<0.05
Carcass traits								
Dressing percentage, %	45.4	47.9	0.215	<0.001	45.7	47.6	0.24	<0.001
Carcass fat score <sup>‡</sup>	3.77	3.21	0.096	<0.001	3.07	3.91	0.077	<0.001
Carcass conformation score <sup>§</sup>	2.63	3.38	0.084	<0.001	2.92	3.10	0.068	<0.05
Carcass weight, kg	20.7	25.7	0.208	<0.001	23.1	23.3	0.20	0.403
Ultrasound fat, cm	0.84	0.78	0.032	0.103	0.74	0.87	0.026	<0.001
Ultrasound muscle, cm	3.05	3.25	0.033	<0.001	3.13	3.17	0.023	0.302
Ultrasound fat gain, cm	0.23	0.26	0.021	0.158	0.22	0.28	0.021	<0.05
Ultrasound muscle gain, cm	0.39	0.59	0.023	<0.001	0.49	0.49	0.023	0.7

\*Total intake (fresh matter weight) = total concentrate intake.

<sup>†</sup>FCR calculated as total feed intake divided by total weight gain.

<sup>‡</sup>1 to 5 scale (1 = low fat cover, 5 = excess fat tissue).

<sup>§</sup>Carcass conformation EUROP scale transformed to 5, 4, 3, 2, and 1, respectively.

**Table 5.** Descriptive statistics for SB and TXSB lambs

	SB					TXSB				
	Mean	SD	Minimum	Maximum	CV %	Mean	SD	Minimum	Maximum	CV %
Slaughter weight, kg	45.7	4.12	37.7	55.0	9.0	53.7	4.970	39.7	66.8	9.3
ADG, g/day	241	81.2	52.7	455.6	33.0	349	98.0	119.0	608	28.4
Total Intake, kg/day*	1.47	0.305	0.91	2.14	20.7	1.63	0.281	1.08	2.36	16.5
FCR <sup>†</sup>	6.74	2.436	3.31	13.99	36.1	5.17	1.212	3.25	11.5	23.4
Dressing percentage, %	45.5	2.243	40.44	51.28	4.9	47.9	2.398	41.5	54.6	5.0
Carcass fat score <sup>‡</sup>	3.77	0.901	1.00	5.00	24.7	3.21	0.724	2.00	5.00	21.5
Carcass conformation <sup>§</sup>	2.63	0.715	1.00	4.00	29.9	3.38	0.749	2.00	5.00	20.7
Carcass weight, kg	20.7	1.86	16.3	25.4	8.9	25.7	2.601	18.0	32.9	10.1
Ultrasound fat, cm	0.84	0.219	0.50	1.50	28.1	0.78	0.205	0.10	1.40	25.0
Ultrasound muscle, cm	3.05	0.241	2.56	3.61	8.2	3.25	2.750	2.77	4.18	8.2

\*Total intake (fresh matter weight) = total concentrate intake.

<sup>†</sup>FCR calculated as total feed intake divided by total weight gain.

<sup>‡</sup>Carcass fat score = 1 to 5 scale (1 = low fat cover, 5 = excess fat tissue).

<sup>§</sup>Carcass conformation EUROP scale transformed to 5, 4, 3, 2, and 1, respectively.

breeds and sexes, respectively, show the variation for each trait. Multiple regression analysis revealed that for ADG, daily intake, breed, and sex cumulatively accounted for 0.574 of the observed variation (Table 7). Age and breed accounted for 0.259 of the observed variation in daily intake. For FCR, breed and sex accounted for 0.176 of the variation observed with 0.145 accounted for by breed. Multiple regression analysis for carcass traits

(Table 8) showed that for dressing percentage, 0.414 of the variation was explained by a combination of breed, sex, ADG, carcass fat score.

### Castration

Ram lambs had greater slaughter weights ( $P < 0.001$ ), total weight gain ( $P < 0.001$ ), FCR ( $P < 0.05$ ), overall ADG ( $P < 0.001$ ), ADG 15–36

**Table 6.** Descriptive statistics for ram and wether lambs

	Ram					Wether				
	Mean	SD	Minimum	Maximum	CV %	Mean	SD	Minimum	Maximum	CV %
Slaughter weight, kg	50.54	5.993	38.70	64.00	11.9	48.9	6.06	37.70	66.8	12.4
ADG, g/day	314	109.1	75.00	555.00	33.5	272	94.0	52.0	608	34.7
Total intake, kg/day*	1.58	0.325	1.01	2.36	20.2	1.57	0.30	0.92	2.09	19.4
FCR <sup>†</sup>	5.58	1.867	3.31	13.99	33.6	6.31	2.18	3.41	21.47	34.7
Dressing percentage, %	45.7	2.581	40.44	54.60	5.6	47.6	2.31	42.3	52.33	4.9
Carcass fat score <sup>‡</sup>	3.07	0.732	1.00	4.00	23.9	3.91	0.68	2.00	5.00	17.4
Carcass conformation <sup>§</sup>	2.92	1.000	1.00	5.00	34.2	3.10	0.90	1.00	5.00	29.2
Carcass weight, kg	23.14	3.316	16.50	30.70	14.3	23.31	3.44	17.25	32.9	14.8
Ultrasound fat, cm	0.84	0.163	0.10	1.30	22.0	0.87	0.22	0.50	1.50	27.7
Ultrasound muscle	3.05	0.3542	2.580	3.570	11.3	3.17	0.32	2.56	4.18	10.2

\*Total intake (fresh matter weight) = total concentrate intake.

<sup>†</sup>FCR calculated as total feed intake divided by total weight gain.

<sup>‡</sup>Carcass fat score = 1 to 5 scale (1 = low fat cover, 5 = excess fat tissue).

<sup>§</sup>Carcass conformation EUROP scale transformed to 5, 4, 3, 2, and 1, respectively.

**Table 7.** Summary of stepwise multiple regression analysis evaluating the relationships between production variables and independent variables in TXSB and SB lambs following a 36-d period on an intensive diet immediately prior to slaughter

	Coefficient (SEM)	95% CI	Contribution to Adjusted $R^2$	$P$ value
ADG, g/day				
Intercept	-0.055 (0.0251)	-0.106 to -0.004	—	<0.0001
Daily intake, g/day	0.038 (0.0972)	0.154 to 0.219	0.459	<0.0001
Breed				
SB	—	—	—	—
TXSB	0.063 (0.0102)	0.043 to 0.084	0.081	<0.003
Sex				
Wether	—	—	—	—
Ram	0.186 (0.0162)	0.019 to 0.058	0.034	<0.01
Cumulative $R^2$			0.574	
Intake, kg/day*				
Intercept	0.937 (0.0958)	0.748 to 1.126	—	<0.001
Age	0.054 (0.0091)	0.036 to 0.072	0.136	<0.001
Breed				
SB	—	—	—	—
TXSB	0.219 (0.0387)	0.143 to 0.296	0.123	<0.001
Cumulative $R^2$			0.123	
FCR <sup>†</sup>				
Intercept	7.095 (0.2322)	6.638 to 7.552	—	<0.001
Breed				
SB	—	—	—	—
TXSB	-1.557 (0.2693)	-2.087 to -1.027	0.145	<0.001
Sex				
Wether	—	—	—	—
Ram	-0.729 (0.2684)	-1.259 to -0.199	0.031	<0.01
Cumulative $R^2$			0.176	

\*Total Intake (Fresh matter weight) = Total concentrate intake.

<sup>†</sup>FCR calculated as total feed intake divided by total weight gain.

d ( $P < 0.001$ ) compared with wether lambs. No differences ( $P > 0.05$ ) were found for total intake ( $P > 0.05$ ), ADG 0–14 d ( $P > 0.05$ ), and daily intake 0–14 d ( $P > 0.05$ ) between sexes. Wether lambs

had greater dressing percentages ( $P < 0.001$ ), fat score ( $P < 0.001$ ), carcass conformation ( $P < 0.05$ ), ultrasound fat ( $P < 0.001$ ), and ultrasound fat gain ( $P > 0.05$ ) in comparison with ram lambs. There

**Table 8.** Summary of stepwise multiple regression analysis evaluating the relationships between carcass variables and independent variables for TXSB and SB lambs following a 36-d period on an intensive diet immediately prior to slaughter

	Coefficient (SEM)	95% CI	Contribution to adjusted $R^2$	$P$ value
Dressing percentage, %				
Intercept	44.263	41.474 to 47.052		<0.001
Breed				
SB	—	—	—	—
TXSB	2.951 (0.4044)	2.151 to 3.749	0.214	<0.001
Sex				
Wether	—	—	—	—
Ram	-1.072 (0.3475)	-1.756 to -0.386	0.128	<0.001
ADG, g/day	-6.219 (2.1442)	-10.448 to -1.200	0.052	<0.001
Carcass fat score	0.488 (0.2142)	0.065 to 0.910	0.020	<0.05
Cumulative $R^2$			0.414	
Ultrasound fat depth, cm*				
Intercept	0.407 (0.0954)	0.219 to 0.595	—	<0.001
Carcass weight	0.024 (0.0044)	0.016 to 0.0315	0.104	<0.001
Sex				
Wether	—	—	—	—
Ram	-0.107 (0.0245)	-0.155 to -0.059	0.080	<0.001
Intake, kg/day	-0.216 (0.0452)	-0.305 to -0.126	0.051	<0.001
Age	0.025 (0.0062)	0.012 to 0.037	0.050	<0.001
Cumulative $R^2$			0.285	
Ultrasound muscle depth, cm†				
Intercept	27.558 (4.5261)	18.629 to 36.487	—	<0.001
Carcass weight, kg	0.678 (0.1424)	0.399 to 0.959	0.383	<0.001
Carcass conformation	0.559 (0.2831)	0.001 to 1.117	0.015	<0.05
Cumulative $R^2$			0.398	
Carcass fat score‡				
Intercept	2.908 (0.5145)	1.894 to 3.923	—	—
Sex				
Wether	—	—	—	—
Ram	-0.767 (0.0995)	-0.962 to 0.572	0.273	<0.001
Carcass weight, kg	0.123 (0.0260)	-0.072 to 0.175	0.039	<0.001
Daily intake, kg/day	-0.116 (0.2190)	-0.547 to 0.316	0.035	<0.002
ADG, g/day	-1.545 (0.7894)	-3.102 to 0.011	0.012	<0.10
Breed				
SB	—	—	—	—
TXSB	-0.696 (0.1466)	-0.985 to -0.407	0.011	<0.001
Cumulative $R^2$			0.391	
Carcass conformation, kg§				
Intercept	0.561 (0.4722)	-0.371 to 1.493	—	—
Breed				
SB	—	—	—	—
TXSB	0.695 (0.1553)	0.390 to 1.002	0.415	<0.001
Carcass weight, kg	0.115 (0.0235)	0.068 to 0.161	0.041	<0.001
Age	-0.103 (0.0251)	-0.152 to -0.053	0.056	<0.01
Carcass fat	0.132 (0.0610)	0.011 to 0.252	0.012	<0.001
Cumulative $R^2$			0.524	
Carcass weight, kg				
Intercept	-10.0608 (0.9697)	8.156 to 11.981	—	—
Breed				
SB	—	—	—	—
TXSB	3.271 (0.3414)	2.597 to 3.944	0.550	<0.001
ADG, g/day	11.054 (1.4391)	8.215 to 13.892	0.113	<0.001
Age	0.386 (0.0631)	0.267 to 0.505	0.043	<0.001
Carcass conformation	0.6173 (0.1782)	0.265 to 0.968	0.015	<0.001
Carcass fat	0.7379 (0.1575)	0.427 to 1.048	0.035	<0.05
Cumulative $R^2$			0.756	

\*Ultrasound fat depth = measurement taken at slaughter.

†Ultrasound muscle depth = measurement taken at slaughter.

‡Carcass fat score = 1 to 5 scale (1 = low fat cover, 5 = excess fat tissue).

§Carcass conformation EUROP scale transformed to 5, 4, 3, 2, and 1, respectively.

was no significant difference between sexes for carcass weight ( $P > 0.05$ ), muscle depth ( $P > 0.05$ ), or ultrasound muscle gain ( $P > 0.05$ ). Ultrasound muscle gain refers to the difference between ultrasound measurements taken on days 0 and 36 of the experiment. For ultrasound fat depth, 0.285 of the variation was explained by carcass weight, sex, age, and intake. For ultrasound muscle depth, carcass weight and carcass conformation score combined accounted for 0.40 of the variation observed. Sex, breed, carcass weight, and ADG accounted for 0.370 of the variation observed for carcass fat score. Likewise for carcass conformation, breed, carcass weight, and carcass fat resulted in an  $R^2$  value of 0.468. For carcass weight, the factors that accounted cumulatively for 0.756 of variation were breed, ADG, carcass conformation, age, and carcass fat.

## DISCUSSION

### *Production Traits*

This study evaluated the production efficiency and carcass traits of SB and TXSB wether and ram lambs following a 36-d intensive feeding period, prior to slaughter. The feeding levels and durations explored in this experiment were representatives of feedlot finishing systems on sheep units in Ireland and the United Kingdom. While the study was designed to evaluate three-way and two-way interactions (among breed, sex, and slaughter age), none were detected, indicating that the effect of castration was consistent across both breed types and different slaughter ages; for this reason, the main effects of breed and sex of the study are presented. The current study demonstrates the superior production performance and efficiency of both TXSB and ram lambs compared with SB and wether lambs, respectively. Multiple regression analysis provided a partial explanation of the factors affecting various production and carcass traits and how much variation these factors explain for a given trait.

ADG in this study was consistently higher for TXSB lambs than for SB lambs, which is in agreement with previous work that has shown that cross-breeding of SB ewes with terminal Suffolk and TX sires increased ADG by 15%–24% (Carson et al., 2001a). Although SB growth rates in the current study were lower than TXSB growth rates, they were nevertheless higher than the growth rates reported for SB lambs of similar ages in the study of Friggens et al. (1997). In the current study, the superiority in ADG of the TXSB over the SB was on average 31% and, therefore, much higher than

that recorded by Carson et al. (2001a). The greater live weight gains of TXSB lambs compared with SB lambs could be explained by the added benefits gained from cross-breeding and the likely genetic improvement of this terminal breed over the past 40 yr as opposed to the SB being a largely unimproved breed. The differing mature weights of the two breed types, as reported by McClelland et al. (1976) and Lewis et al. (2004), could also help to possibly explain the increased growth rates of TXSB lamb.

The higher growth rates in ram lambs observed in the present study agree with the growth rates found by Lee (1986a). The 15% higher ADG for ram compared with wether lambs is in close agreement with the results of the studies of Fogarty and Mulholland (2012) and Fogarty et al. (2000) but lower than the 39% higher ADG reported for Border Leicester ram compared with wether lambs by Lee (1986b). Increased gains in ram lambs are associated with male sex hormones such as testosterone (Kiyma et al., 2000) which stimulates increased dietary nitrogen utilization efficiency, an action that is also accompanied by decreased fat deposition (Judge, 1989; Lawrence and Fowler, 1997). The differences shown in ultrasonically determined fat depth between breed types in this study reflect the leaner carcasses produced by ram lambs compared with wether lambs.

Other studies (Webster, 1980) have suggested that lower ADG in ram lambs may be due to lower feed intake compared with wethers, while the higher heat production of ram lambs was believed to reduce their efficiency in utilizing energy for growth. This study does not support either of those hypotheses, as ram lambs had equal intake to wether lambs and were more efficient at converting feed to live weight gain. Also, in the current study, lambs were individually penned and had little opportunity to expend energy on sexual activity compared with lambs in larger pens and or at pasture; however, in commercial scenarios when lambs are grouped penned for finishing, if animals are given sufficient time to acclimatize to other lambs in the pen, and no additional lambs are added over the finishing period, then mounting/fighting should not be an issue.

In this study, SB lambs had a 10.75% lower feed intake than TXSB lambs which is smaller than the 15%–20% lower intake recorded in SB lambs by Wooliams and Wiener (1983) who compared TX and Suffolk crossbred lambs with SB lambs and also lower than the 14%–21% difference recorded by Carson et al. (2001a) who compared SB with TXSB lambs. The higher feed intake in the TXSB lambs would also contribute to their higher growth



rates; the difference observed between rams and wethers may be more attributable to efficiencies rather than intake, as no intake differences were observed between the wether and ram lambs. Feed intake was similar for rams and wethers across both breed types which in contrast with previous work which has concluded that superior intake in ram lambs is a factor causing higher gains (Wynn and Thwaites, 1981). The economic importance of feed intake has been highlighted by Wooliams and Wiener (1983). TXSB lambs would be expected to have a higher mature weight and thus greater maintenance requirements to explain their greater intakes.

FCR, expressed as the amount of feed required for the production of a unit of weight gain, has an important impact on the economics of any lamb finishing system, as the more efficient lambs require less feed per unit gain and, are therefore, more profitable (Yeaman et al., 2013). Speijers et al. (2009) reported TXSB lambs to be significantly more efficient than purebred SB though the study of Carson et al. (2001a) reported little difference in FCR for a range of hill lamb crosses. The results of the current study are also consistent with the reported superior efficiency of terminal breed crosses compared with hill lambs (Lewis et al., 2004).

Data on breed and castration differences for post weaning performance are very useful to producers when determining the value of lambs. In the current study and, within both breed types and wether and rams, wide variation was also recorded for FCR, similar to other production traits already discussed. The descriptive analysis showed superior FCR of TXSB which had a range from 3.25 to 11.52 kg, while the SB lambs had a range from 3.31 to 13.99 kg. Regression analysis showed that breed and sex combined accounted for 21.33% of variation. Greater FCR can be attributed to the terminal traits in the TXSB; these greater efficiencies of TXSB are very important in production situations as they can reduce days to slaughter. Differing degrees of efficiencies may also result from differing levels of nutrient digestion and utilization or the efficient of use of nutrients for growth of different body tissues. Some studies in beef cattle have reported that live weight can affect FCR through its effect on maintenance requirements and production needs, suggesting that the heavier lamb has greater maintenance requirements and thus a lower FCR (Morris, 2003). In the current study, the slaughter weight of lambs was included in the regression analysis but did not affect FCR. Levels of variation observed for production traits indicate the greatest

variation was for ADG and FCR, above 30% coefficient of variation was observed for both traits, while total intake had a coefficient of variation in the region of 20% for each breed and sex. The levels of variation observed for ADG in this study are greater than the 15.1% observed in the study of (Carson et al., 2001a) and 18.52% as reported by (Speijers et al., 2009) and may be explained due to the fact that lambs in this study were slaughtered after a fixed feeding duration and not at a given live/slaughter weight. Greater levels of variation for these traits were observed for SB lambs compared with TXSB lambs; this may be explained by the terminal genes added by TX rams which have been selected for terminal traits and result in a slightly more uniform range for these traits compared with SB lambs.

### *Carcass Traits*

Lambs are selected for slaughter in Ireland and the United Kingdom on a combination of live weight and fatness with an emphasis on producing a 19–23 kg carcass with sufficient fat cover (score 3 seen as ideal) and a conformation score that falls between E and R on the EUROP scale to meet market specification for both the Irish and export markets. The market specification for carcass weight increases as the year progresses; the current study investigated the potential of both genotypes to meet these specifications.

Kill out percentage was greater in TXSB lambs (+2.5 percentage points) compared with SB lambs, while wether lambs had a greater dressing percentage (+1.8 percentage points) compared with ram lambs. This is in agreement with Speijers et al. (2009), who reported a 2.5 percentage increase in favor of TXSB compared with SB lambs and also an increased dressing percentage in wether lambs compared with ram lambs. The lower dressing percentage in ram lambs can be partially attributable to the weight of the testes and heavier horns, particularly in SB ram lambs, which directly contributes to final live weight but not to carcass weight. Besides the above, dressing percentage differences between ram and wether lambs may be attributed to the heavier liver, lungs, and heart in ram lambs compared with wether lambs (Morgan and Owen, 1973). Furthermore, Kirton et al. (1995a) reported that progeny of longer wool breeds, to which SB could be assigned, had a dressing percentage which was 2–3 percentage points lower than shorter wool breeds such as TX. The recorded range in dressing percentage between the two breeds varied between

40.4% and 54.6%, whereas a range between a minimum of 40.44% and a maximum of 52.33% were observed between rams and castrates. From the results of the study, we can conclude that breed and castration were the two biggest factors contributing to variation seen in dressing percentage, with breed and castration accounting for 21.42% and 12.77% of the variation, respectively.

The differences reported in the fat cover between the two breeds could be explained by the early maturation of SB lambs and increased deposition of adipose tissue at a lighter weight compared with the later maturing influence of a TX sire on the TXSB lambs. Also, it is documented that lambs of a higher mature weight potential, growing toward maturity, will be less fat at any given weight compared with an animal of lower mature weight potential. Mainly, because lambs are at a lower proportion of their mature weight, thus are still utilizing the energy for growth and muscle development instead of lay down fat which may be happening with the SB lambs in this study (Wood et al., 1980). In the current study, ram lambs produced carcasses which resulted in an ideal fat score of 3.07, while wether lambs yielded carcasses with an excessively high mean fat score of 3.91. The leaner carcasses produced by ram lambs compared with wether lambs is consistent with the reports of Lee et al. (1990) and Hopkins et al. (1991). High carcass fat cover is a nondesirable attribute for processors. The wide range observed in fat cover between breed as well as between ram and wether lambs are documented by the minimum and maximum values for breed in Table 5. Also, Table 5 shows that the range was from a score of 1 to 5, while Table 6 reports a range from a score of 2 to 5 between ram and wether lambs.

Improvement in lamb conformation from hill flocks is critical as conformation is incorporated into the payment system. TXSB produced carcasses with better conformation compared with SB lambs. The clear potential to improve conformation score by almost 0.75 of a unit in the current study by cross-breeding is in agreement with Carson et al. (2001b), Carson et al. (1999), and Speijers et al. (2009) all of whom used the EUROP carcass conformation scoring scale and reported improvements in carcass conformation similar to those observed in the current study. Increasing the proportion of terminal sire genes in the lamb, while simultaneously decreasing the proportion of hill breed genes, would be expected to further increase carcass conformation as evidenced by the 1.6 unit improvement in conformation reported by Carson et al.

(1999) in TX lambs relative to SB lambs. A linear reduction in conformation score as the proportion of hill genes increases shows the profound effect hill breed genes have on carcass conformation (Dawson et al., 2003). Speijers et al. (2009) reported that 83% of crossbred lambs yielded a carcass of E, U, or R compared with 40% of SB lambs. The regression analysis in the current experiment shows that breed accounted for 41.5% of variation in conformation score thus confirming the potential to increase carcass conformation score by cross-breeding.

Carcass weight in the present study was greatest in TXSB lambs, which is a direct result of their superior live weight and higher dressing percentage, with TXSB yielding an additional 5 kg of carcass compared with SB lambs. No difference was observed in carcass weight between ram and wether lambs although ram lambs were heavier at slaughter; this is due to higher dressing percentage achieved by wether lambs.

Ultrasonic measurements are increasingly used in breed improvement programmes as a noninvasive measure of carcass lean meat content. Ultrasound fat depth prior to slaughter was greater in wether lambs which agree with the carcass fat score data. However, ultrasound fat depth at slaughter did not differ between breeds. As the ultrasound measurement is only made at one point on the carcass, determination of fatness may be better gauged from the overall carcass score. Regression analysis revealed that variation in ultrasonic fat depth was predominately explained by carcass weight (10.4%) and sex (8%) of the lamb, with wether lambs depositing more fat at a similar weight and after a similar duration of feeding than ram lambs, supporting the increased subcutaneous carcass fat cover scores recorded. The TXSB lambs produced carcasses with greater amounts of muscle when measured ultrasonically and gained more muscle than SB lambs, as would be expected given the superior terminal traits of the TX breed. While ram lambs had increased muscle depths when compared with wethers but no increased muscle gains over the feeding period were observed in rams compared with wethers. Regression analysis revealed that as carcass weight increased by 1 kg, ultrasonic muscle depth increased by 0.678 cm, and each increase in conformation score increased ultrasound muscle depth by 0.559 cm. Greater variation in carcass conformation and carcass fat score in SB lambs compared with TXSB can be attributed to the greater terminal attributes added by the TX, greater variation in wether lambs than ram lambs indicates a more uniform performance for ram lambs. The

study of Speijers et al., (2009) reported a 10% variation in FCR between SB lambs and TXSB lambs. Likewise, the same study reported much lower levels of variation between carcass conformation and fat score than our study. However, in the study Speijers et al., (2009), animals were slaughtered at a uniform weight rather than after a set feeding duration, which may help to explain some of the observed variations. The results of the current study record greater variation between SB and TXSB lambs than in the study of Carson et al., (2001b), in which SB and TXSB variation levels of 15.7% and 12.5% were observed for carcass fat score, respectively. At similar carcass weights, the study of Carson et al., (2001b) reported similar levels of variation for carcass weights as the current study, reporting 5% and 6%, respectively, for SB and TXSB lambs.

High levels of variation within both breeds and as a result of castration highlight the variation faced by producers at commercial level when purchasing store lambs for finishing. Further work may be justified in order to identify some of the reasons for these high levels of variation within animals of the same breed and gender. The results of this study suggest cross-breeding has the potential to increase the viability of some hill systems by increasing the performance potential of the lambs produced. The amount of cross-breeding which occurs within a flock is dependent on the number of replacement females required (Purebred). Other factors such as the severity of conditions on the hills and the ability for crossbred lambs to survive. However, where conditions are favorable and systems allow cross-breeding should be practiced, particularly in ewes which are not selected for breeding replacement females for the hill flock. These results focus on the terminal traits of male lambs; however, it must also be noted that a vibrant market also exists for hill cross females lambs, which are sourced by lowland breeds as replacement ewes. The study of Annett et al. (2011) concluded that sourcing replacement females by crossing SB ewes with terminal breeds such as Lyeln, TX, and Cheviot can lead to significant improvements in the productivity of hill flocks.

## CONCLUSION

It can be concluded from this study that TXSB lambs have superior growth rates and FCR, resulting in higher carcass weights with better conformation and leaner carcasses than SB lambs. This would suggest that the use of a terminal type sire such as the TX offers an opportunity to improve the sustainability of hill sheep farm systems by

allowing producers to increase carcass output while achieving greater production efficiencies. Notwithstanding this, it must be noted that SB lambs reach acceptable carcass weights to meet market specifications; however, they may need to be slaughtered at lighter weights, particularly for wether lambs, to avoid over fat carcasses being produced. Although ram lambs have greater FCR and ADG, which result in a higher slaughter weight, no differences in carcass weights are observed due to the superior dressing percentage of wether lambs. However, wether lambs produce carcasses with a higher fat cover than ram lambs, which is an undesirable trait for lamb carcasses. The results of this study indicate that there are little benefits to be gained by castrating lambs from a performance point of view; however, castration may need to be practiced on some farms as a management tool. Castration may also be required for certain markets as some markets have preferences for castrated lambs rather than intact males. Further research is required to establish the effect of castration on meat quality in these production systems. A feature of this study was the wide variation in performance traits, particularly growth rate, observed within breeds and between wether and ram lambs.

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