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

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**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 purebred 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 ±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 average daily gain (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 to 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 to SB while wether lambs had greater dressing percentages compared to 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 to 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.

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Key Words: carcass, crossbreeding, lamb, performance, castration

## INTRODUCTION

Scottish Blackface (SB) ewes account for approximately 29% of the 2.64 million national ewe breeding flock in Ireland and are predominately maintained on hill and marginal land unsuitable for more intensive livestock farming systems (DAFM, 2016). The SB breed traditionally produced light carcasses (10kg-15kg) 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-SB crossbred (TXSB) lambs. The TXSB lambs, as a result of their added terminal genes compared to 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 results in higher levels of lamb performance, though prolonged periods of concentrate feeding, which may be necessary for light hill lambs leads to increased production costs (Keady and Hanrahan, 2015). To offset some of these production costs ram lambs are favoured 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 behaviour 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 Texel cross SB genotypes. The objective of this study was to compare the production performance and carcass characteristics of purebred SB and crossbred TXSB ram and

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wether lambs fed on an intensive all-concentrate diet for a 36-day 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).

### *Pre-study 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 days, respectively. Lambs were identified at birth on six commercial source farms (Table 2) and a weight was recorded for each lamb within 1hr 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 months 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 3 farms produced TXSB lambs. On each farm 5 rams of each breed was used (Table 2) Prior to weaning lambs were reared initially on in-bye land (low green land land grazing pasture) and at about one month of age 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 ten heaviest lambs were selected for the finishing period for each of the five slaughter time points. This

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randomised complete block design was favoured 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) 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 (d 0), lambs were offered 150 g/d fresh weight of concentrate feed on d -12, -11 and -10 increasing by 100 g/d fresh weight concentrate on each day from d -9 to d -1 to minimise 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 $55^0$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 1UFL/kg fresh weight (Table 3).

*Animal Measurements*                                                                                       On   d   0 (start of 36 d intensive feeding period) lambs were weighed (without food or water restriction) and ultrasonically scanned (Dynamic Imaging, Livingstown, 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 3rd lumbar vertebra; subcutaneous back fat thickness was measured directly above the eye muscle at this point, lambs were ultrasonically scanned again on d 36. Body weight was also recorded at 7 d intervals.

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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. Average daily 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 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 pre slaughter 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, USA). Production and carcass data as well as summary statistic were analysed 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

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value was chosen. All data presented in the tables were expressed as least squares means ± 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., Cary, NC, USA) 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 3; 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 to 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 d and 36 d) (*P* < 0.001) compared to 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)

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and ultrasound fat gain ($P > 0.05$), the later defined as the difference the between ultrasound fat measured on d 0 and d 36 of the experiment. The summary statistics are presented in Tables 5 and 6 for the two 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 d ($P < 0.001$) compared to 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 to ram lambs. There was no significance 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 d0 and d36 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 day intensive feeding period, prior to slaughter. The feeding levels and durations explored in this experiment were representative of feedlot finishing systems on sheep units in Ireland and the United Kingdom. While the study was designed to evaluate 3-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 to 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.

Average daily gains in this study were consistently higher for TXSB lambs than for SB lambs which is in agreement with previous work which has shown that cross breeding of SB ewes with terminal Suffolk and Texel 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 to SB lambs could be explained by the added benefits gained from crossbreeding and the likely genetic improvement of this terminal breed over the past 40 years 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 to wether lambs is in close agreement with

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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 to 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 to wether lambs.

Other studies (Webster, 1980) have suggested that lower ADG in ram lambs may be due to lower feed intake compared to wethers, while the higher heat production of ram lambs was believed to reduce their efficiency in utilising 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 to 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 acclimatise 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 Texel 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). Texel cross Scottish Blackface lambs would

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be expected to have a higher mature weight and thus greater maintenance requirements to explain their greater intakes.

Feed conversion ratio, 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 to 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 3.25kg to 11.52kg while the SB lambs had a range from 3.31 kg 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 utilisation 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

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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 to TXSB lambs, this may be explained by the terminal genes added by Texel rams which have been selected for terminal traits and result in a slightly more uniform range for these traits compared to SB lambs.

*Carcass traits*

Lambs are selected for slaughter in Ireland and the UK on a combination of live weight, and fatness with an emphasis on producing a 19-23kg 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 to SB lambs while wether lambs had a greater dressing percentage (+1.8 percentage points) compared to ram lambs. This is in agreement with Speijers et al. (2009), who reported a 2.5 percentage increase in favour of TXSB compared to SB lambs and also an increased dressing percentage in wether lambs compared to 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 to 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 Texel. The recorded range in dressing percentage between the two breeds varied between 40.4% and 54.6%, where as 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

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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 to the later maturing influence of a Texel sire on the TXSB lambs. Also, it is documented that lambs of a higher mature weight potential, growing towards maturity will be less fat at any given weight compared to an animal of lower mature weight potential. Mainly, because lambs are at a lower proportion of their mature weight, thus are still utilising 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 to wether lambs is consistent with the reports of Lee et al. (1990) and Hopkins et al. (1991). High carcass fat cover is a non-desirable 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 Tables 5 show 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. Texel cross Scottish Blackface lambs produced carcasses with better conformation compared to SB lambs. The clear potential to improve conformation score by almost 0.75 of a unit in the current study by crossbreeding 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

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evidenced by the 1.6 unit improvement in conformation reported by Carson et al. (1999) in Texel lambs relative to Scottish Blackface 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 to 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 crossbreeding.

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 5kg of carcass compared to 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 non-invasive measure of carcass lean meat content. Ultrasound fat depth prior to slaughter was greater in wether lambs which agrees 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 Texel breed. While ram lambs had increased muscle depths when compared to wethers but no increased muscle gains over the feeding period were observed in rams compared to wethers. Regression analysis revealed that as carcass weight increased by 1kg, ultrasonic muscle depth increased by 0.678cm and each increase in conformation score increased ultrasound

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muscle depth by 0.559cm. Greater variation in carcass conformation and carcass fat score in SB lambs compared TXSB can be attributed to the greater terminal attributes added by the Texel, 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 variation. 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 crossbreeding has the potential to increase the viability of some hill systems by increasing the performance potential of the lambs produced. The amount of crossbreeding 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 favourable and systems allow crossbreeding should be practised, 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, Texel and Cheviot can lead to significant improvements in the productivity of hill flocks.

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**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 Texel 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 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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**TABLES**

**Table 1.** Minimum and maximum age of Scottish Blackface (SB) and Texel cross Scottish Blackface (TXSB) lambs across months of slaughter

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

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**Table 2.** Contribution of the number Scottish Blackface (SB) and Texel cross Scottish Blackface (TXSB) from each source farm.

| Farm | No SB lambs | No SB Rams used | No TXSB Lambs | No Texel 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 |

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**Table 3.** Ingredient and chemical composition of concentrate and silage fed to Texel cross Scottish Blackface and Scottish Blackface 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 |

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| | Breed | | | | Sex | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | SB | TXSB | SEM | P-Value | Ram | Wether | SEM | P-Value |
| **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[1] | 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[2], kg | 6.74 | 5.17 | 0.201 | <0.001 | 5.58 | 6.31 | 0.200 | <0.05 |
| | | | | | | | | |
| **Carcass Traits** | | | | | | | | |
| Drerssing percentage, % | 45.4 | 47.9 | 0.215 24 | <0.001 | 45.7 | 47.6 | 0.24 | <0.001 |
| Carcass fat score[3] | 3.77 | 3.21 | 0.096 | <0.001 | 3.07 | 3.91 | 0.077 | <0.001 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Carcass conformation score[4] | 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 |

**Table 4.** Least squares means for production and carcass traits for Scottish Blackface (SB) and Texel cross Scottish Blackface (TXSB)) rams and wethers including standard error of the means (SEM).

[1]Total Intake (Fresh matter weight) =Total concentrate intake, [2]FCR calculated as total feed intake divided by total weight gain, [3]1 to 5 scale (1=low fat cover, 5=excess fat tissue),[4]Carcass Conformation EUROP Scale transformed to 5, 4, 3, 2 and 1, respectively.

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**Table 5.** Descriptive statistics for Scottish Blackface (SB) and Texel cross Scottish Blackface (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] | 1.47 | 0.305 | 0.91 | 2.14 | 20.7 | 1.63 | 0.281 | 1.08 | 2.36 | 16.5 |
| FCR[2] | 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[3] | 3.77 | 0.901 | 1.00 | 5.00 | 24.7 | 3.21 | 0.724 | 2.00 | 5.00 | 21.5 |
| Carcass conformation[4] | 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 |

[1]Total Intake (Fresh matter weight) =Total concentrate intake, [2]FCR calculated as total feed intake divided by total weight gain, [3]Carcass fat score=1 to 5 scale (1=low fat cover, 5=excess fat tissue), [4]Carcass Conformation EUROP Scale transformed to 5, 4, 3, 2 and 1, respectively.

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**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] | 1.58 | 0.325 | 1.01 | 2.36 | 20.2 | 1.57 | 0.30 | 0.92 | 2.09 | 19.4 |
| FCR[2] | 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[3] | 3.07 | 0.732 | 1.00 | 4.00 | 23.9 | 3.91 | 0.68 | 2.00 | 5.00 | 17.4 |
| Carcass conformation[4] | 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 |

[1]Total Intake (Fresh matter weight) =Total concentrate intake, [2]FCR calculated as total feed intake divided by total weight gain, [3] Carcass fat score=1to 5 scale (1=low fat cover, 5=excess fat tissue), [4]Carcass Conformation EUROP Scale transformed to 5, 4, 3, 2 and 1, respectively.

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

| | Coefficient (SEM) | 95% Confidence intervals | 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[1]** | | | | |
| 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[2]** | | | | |
| 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 | |

[1]Total Intake (Fresh matter weight) =Total concentrate intake, [2]FCR calculated as total feed intake divided by total weight gain

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

| | Coefficient (SEM) | 95% Confidence intervals | 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[1]** | | | | |
| 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[2]** | | | | |
| 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[3]** | | | | |
| 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[4]** | | | | |
| Intercept | 0.561 (0.4722) | -0.371 to 1.493 | - | - |
| Breed | | | | |
|   SB | - | - | - | - |

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| | | | | |
|---|---|---|---|---|
| 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 | |

[1]Ultrasound fat depth=Measurement taken at slaughter, [2]Ultrasound muscle depth= Measurement taken at slaughter, [3] Carcass fat score=1to 5 scale (1=low fat cover, 5=excess fat tissue), [4]Carcass Conformation EUROP Scale transformed to 5, 4, 3, 2 and 1, respectively

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