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J. M. Macfarlane
Scottish Agricultural College, j.macfarlane@sac.ac.uk

R. M. Lewis
Scottish Agricultural College, Virginia Polytechnic Institute andState University, ron.lewis@unl.edu

G. C. Emmans
Scottish Agricultural College

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Growth and carcass composition of lambs of two breeds and their cross grazing ryegrass and clover swards

J. M. Macfarlane[1]†, R. M. Lewis[1, 2] and G. C. Emmans[1]

[1]*Sustainable Livestock Systems, Scottish Agricultural College, West Mains Road, Edinburgh EH9 3JG, UK*
[2]*Department of Animal and Poultry Sciences (0306), Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA*

† E-mail : j.macfarlane@sac.ac.uk.

Abstract

The effects of sward, breed type and sex on lamb growth and carcass composition were measured at two degrees of maturity in live weight. The three breed types were Scottish Blackface (no. = 60), Suffolk (no. = 59) and their reciprocal crosses (no. = 60). The lambs grazed swards of either ryegrass, clover or a mixed sward intended to contain both. The proportion of the mixed sward as clover was only 0·014. Each lamb was scanned using X-ray computed tomography to measure the weights of fat, lean and bone in the carcass at two proportions of mature body weight (0·30 and 0·45). Live weights were recorded weekly. Average daily gains (ADG) in live weight and carcass tissues were calculated for each lamb between the 0·30 and 0·45 stages of maturity.

At the 0·30 stage of maturity, breed type differences in carcass composition were small; the Scottish Blackface had 0·942 as much bone as the Suffolk lambs (P < *0·001), with the cross lambs intermediate. At the 0·45 stage of maturity, Scottish Blackface lambs had less fat (0·749 times as much;* P < *0·001), more lean (1·065 times as much;* P < *0·001) and more bone (1·055 times as much;* P < *0·001) than did Suffolk lambs. The values for crossbred lambs were intermediate but closer to those of the Suffolk. Neither sward nor its interaction with breed type had any significant effect on carcass composition at either the 0·30 or 0·45 stage of maturity. The effect of sex on carcass composition was significant at the 0·45 stage of maturity when castrated male lambs had less fat* (P < *0·001) and more lean* (P < *0·001) than female lambs. There were breed type by sward interactions for ADG in live weight* (P < *0·05), in carcass weight* (P < *0·001), and in fat* (P < *0·001) and bone weights* (P < *0·05). The interactions were such that Suffolk lambs had higher growth rates than Scottish Blackface lambs on clover but not on ryegrass or the mixed sward. There were no significant differences between Suffolk and crossbred lambs in growth rates on any sward. In this, and in two other experiments, the extent to which growth rate declined as the nutritional environment became worse was greater* (P < *0·05) in Suffolk than in Scottish Blackface lambs; that is, Suffolk lambs expressed greater environmental sensitivity than the Scottish Blackface.*

Keywords: *carcass composition, clover, growth, ryegrass, sheep.*

Introduction

In domestic breeds of sheep, differences in mature size are responsible for much of the variation in carcass composition at a given weight (Taylor *et al.*, 1989). This is true even where breeds have different rôles within the sheep industry (Wood *et al.*, 1980). Feeding can affect lamb carcass composition at the same degree of maturity (Mahgoub *et al.*, 2000; Chakeredza *et al.*, 2001; Lewis *et al.*, 2002 and 2004b) for a given breed. It is also possible that there are interactions between breed or, more generally, genotype and feeding treatment, that may affect growth rate and efficiency (Lewis *et al.*, 2002), and carcass composition (Lewis *et al.*, 2004b). Such effects are of considerable theoretical and practical interest.

The experiment reported here is part of a series that includes work on pure Suffolk sheep (Lewis *et al.*, 2002 and 2004a) as well as different breed types (Lewis *et al.*, 2004b; Macfarlane *et al.*, 2004). The aim is to help producers to effectively combine breed and management systems in order to efficiently produce high quality lamb. In this study, lambs were grazed on swards of either ryegrass, clover or a sward intended to be composed of a mixture of the two. The objective was to see to what extent the swards used affected the differences between the breeds in growth and carcass composition.

Material and methods

Animals and their management

Ewes of the Scottish Blackface (no. = 87) and Suffolk (no. = 91) breeds were mated to rams of the Scottish Blackface (no. = 7) and Suffolk (no. = 6) breeds to produce lambs that were purebred Scottish Blackface (B), purebred Suffolk (S) or either of the two crosses, in both 2000 and 2002. The ewes and rams used were sourced from several commercial flocks with the intent of fairly representing the characteristics of these breeds. Of the total, 15 B and 14 S ewes were used in both years, as were two of the rams from each breed.

Litter size, lamb weight, sex, and whether the lambing was difficult or not, were recorded at birth. The mean birth date was 9 March (s.d. 6·4 days). Ram lambs were castrated shortly after birth. Lambs were reared either as twins or singletons. For each set of triplets, one lamb was cross-fostered to a ewe of the same dam breed that either had a single lamb or had lost her own lamb. Lambs were weighed weekly throughout the experiment.

On reaching target weights of 0·30 of estimated mature weight or 10 weeks of age, whichever came sooner, the lambs were weaned. The lambs were scanned at 0·30 and 0·45 of their mature weights. These were estimated to be 69 kg for the Scottish Blackface (Friggens *et al.*, 1997) and 100 kg for the Suffolk (Lewis *et al.*, 1998). The mature size assumed for the crossbred females was 88 kg, which allows for an effect of heterosis of 4% for mature weight in sheep (Nitter, 1978). The mature weight of the castrate males was assumed to be the same as that of females.

At weaning, each lamb was allocated randomly, within breed type, sex and half-sib sire family, to a sward of perennial ryegrass (*Lolium perenne*), white clover (*Trifolium repens*) or one intended to be a mixture of the two. The target number was 10 lambs for each sex, breed type and sward combination over the 2 years giving 180 lambs in total. In all but seven of the 18 treatments (2 sexes × 3 breed types × 3 swards) this was achieved; in three cases there were 11, and in four cases nine lambs. In each year, lambs on a given treatment were then allocated to one of two replicate plots, with five lambs of each breed type per plot. For each breed type, one of the plots was selected to have three females and two males, while the other plot had two females and three males. The sex balance was maintained as closely as possible across plots. The site was near Penicuik, Scotland, UK (latitude 55°51'N).

Sward establishment and management

Lambs grazed on six paddocks totalling 5·48 ha. The paddocks were sown in 1998 and comprised two plots of each of perennial ryegrass (35 kg seed per ha), white clover (5 kg seed per ha) and a mixture between these two (35 kg ryegrass seed and 2 kg clover seed per ha). Sheep had grazed the paddocks in both 1998 and 1999. Swards were maintained at a height of 6 cm in the early part of the season, rising to 8 cm as the season progressed. The biomass on offer was measured every 14 days, using quadrants (0·25 m × 1 m), from late March through to the end of the study in late October. Fifteen randomly selected sites were measured within each paddock, and cut to within 0·5 cm of ground level with battery operated shears. The samples were then bagged, weighed fresh, dried (24 h in an oven at 60°C), and then weighed again to determine dry matter contents.

As expected, there were marked changes in dry biomass as the season progressed (Figure 1). The mean values for the three swards across all measurements (years, plots and sampling times) are

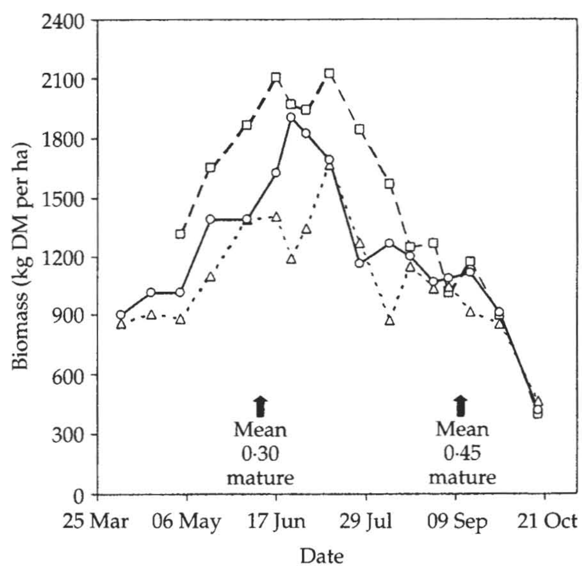

Figure 1 Weight of biomass (kg dry matter (DM) per ha) for the ryegrass sward (△), the mixed sward (○) and the clover sward (□) by day and month of sampling.

Table 1 *Description of the swards*

Sward	Biomass (kg/ha)		DM† (g/kg)	Proportion of DM as:‡		Sward composition (g/kg DM)§		
	Fresh	Dry		Ryegrass	Clover	CP	NCGD ‖	Ash
Ryegrass	5590	1052	195·9	0·967	0·000	139	747	90
Mixed	6230	1212	199·1	0·938	0·014	141	747	90
Clover	10930	1555	149·5	0·017	0·692	244	795	106
s.e.d.	427	65·2	5·53	0·0151	0·0191			

† Dry matter.
‡ The balance of DM was as made up of other grasses and weeds.
§ Estimated from composition of ryegrass, clover and other plant species and their proportions in the swards. No standard errors were calculated.
‖ NCGD = neutral cellulase gamanase digestibility.

shown in Table 1. Both dry and fresh biomass were greater ($P < 0{\cdot}001$) for the clover than for the other two swards, with the mixed sward intermediate. The crude protein contents and digestibilities of the three swards are shown in Table 1, as are the proportions of the herbage dry matter as grass and clover in each sward. The sward that was intended to be mixed had only a small proportion of clover (mean 0·0136, s.e. 0·0116).

Measurements
It was intended to scan each lamb, using X-ray computed tomography (CT), at both 0·30 and 0·45 of its estimated mature weight. Each lamb was scanned in cross-section at three sites: near the shoulder (sixth thoracic vertebra; TV6), along the loin (second lumbar vertebra; LV2) and at the hind leg (ischium, ISC). Areas (mm^2) of fat, lean and bone were measured from the scans at all three sites.

The achieved stages of maturity were slightly lower than those intended: mean 0·298, (s.d. 0·00077) at the 0·30 stage of maturity, and mean 0·436 (s.d. 0·00185) at the 0·45 stage of maturity. Some lambs needed to be scanned before they had achieved their 0·45 stage of maturity because the swards became unable to support growth late in the season. The deviation of the actual degree of maturity from that intended was used as a covariate in the analysis of the composition variables at both stages of maturity, and used to adjust the predicted values of the means to the target stages of maturity. No covariate was used for the variables describing the interval between the two scans. The mean dates at the 0·30 and 0·45 scans were 8 June (s.d. 31 days) and 11 September (s.d. 37 days), respectively.

Derived variables
Weights of fat, lean and bone in the carcass at each scan were estimated from the tissue areas given by the CT scans, and live weight. The prediction equations used came from previous calibration trials at the SAC-BioSS CT scanning unit on the two pure breeds (M. Young, personal communication), which covered a wider range of weights than considered in this experiment. Following Lewis *et al.* (2004b), the weights in the crossbred lambs were predicted using the mean of the coefficients of the two pure breeds.

Carcass weight was calculated as the sum of the predicted weights of fat, lean and bone in the carcass. Proportions of each tissue in the carcass (g/kg) for each lamb were then calculated at both scanning events. Average daily gains in live weight (ADG g/day), and in estimated carcass and tissue weights, were calculated for each lamb between the scans at the 0·30 and 0·45 stages of maturity. The composition of the gain between the two scanning events was calculated.

Statistical methods
As no large or significant differences in performance could be demonstrated between the reciprocal crosses, the two groups were combined as 'the cross' (X) in all analyses. The replicate plots of each sward were treated as blocks for purposes of statistical analysis. The residual maximum likelihood procedure (REML; Genstat 6 Committee (2002)) was first used to fit a general linear model (GLM) that reflected the split-plot design of the trial.

The general form of the mixed linear model considered in the analyses was:

$$Y_{ijklm} = \mu + R_i + S_j + e^A_{ij} + T_{(ij)k} + B_l + (SB)_{jl} + e^B_{(ij)kl} + \mathbf{X}\beta + e^C_{(ijkl)m} \quad (1)$$

where Y_{ijklm} was the response variable for a lamb ($m = 1, \ldots, a$; $a = 5$) of breed type B ($l = 1, \ldots, b$; $b = 3$) randomly assigned in year T ($k = 1, \ldots, t$; $t = 2$) to sward S ($j = 1, \ldots, s$; $s = 3$) in block R ($i = 1, \ldots, r$; $r = 2$), where $(SB)_{jl}$ was the sward by breed type interaction, $\mathbf{X}$ the design matrix relating levels of covariates to the lamb to which they pertain and β

Table 2 *Least-square means of proportions of fat, lean and bone in the carcass (g/kg) for lambs weaned on either a weight or an age basis, and for female and castrate lambs, at their 0·30 and 0·45 stages of maturity*

	Weaning criterion by:			Lamb sex		
	Weight	Age	s.e.d.	Female	Castrate	s.e.d.
0·30 maturity						
Fat	154·3	69·4	6·75***	121·7	101·9	5·73*
Lean	647·5	708·3	5·73***	671·3	684·5	4·91
Bone	198·2	221·5	3·04***	206·7	213·0	2·57
0·45 maturity						
Fat	192·9	192·6	5·11	203·3	182·2	4·34***
Lean	626·4	626·6	4·22	618·9	634·1	3·69***
Bone	181·0	181·2	1·94	178·3	183·9	1·64***

was a vector of linear regression coefficients. The random terms included block (R_i), block by sward interaction (e^A_{ij}), year nested within the block by sward interaction ($T_{(ij)k}$), year by breed type interaction nested within the block by sward interaction ($e^B_{(ij)kl}$), and the residual error ($e^C_{(ijkl)m}$).

Weaning category (either age or weight based) and sex (female or castrated male) had significant effects and were always included as fixed effects in the models fitted. The effects of including litter size (1, 2 or more), rearing type (single or twin), dam age (2 and 3 year old or 4+ years old), whether assistance at lambing was or was not required, and whether the lambs were raised by their genetic dam or a foster dam, were tested. None accounted for significant variation in any response variable considered and they were therefore excluded from the final model fitted. Birth weight, as the deviation of an observation from the relevant breed type by sex mean, was initially considered as a covariate; it was never significant and was therefore excluded from final model. The fixed effects included in the final mixed model included only sex and weaning category, and the design variables (block, sward, year and breed type).

The actual stage of maturity at scanning, as a deviation from the target value, was considered as an additional covariate in the model used to describe treatment effects on carcass composition at the two stages of maturity. It was significant, but as its interactions with breed type and sward effects were found to be non-significant, it was included as a simple covariate.

When the model was fitted, negative estimates of the variance were obtained for some of the random terms and thus relationships among mean squares were inconsistent with expectations. As this was not sensible, the model was fitted again including only those random terms that had a positive estimate for their variance component and gave the expected relationships among the mean squares. For tissue proportions, this approach resulted in $T_{(ij)k}$ and $e^C_{(ijkl)m}$ being included as the only random terms in the final mixed model considered. For rates of gain variables, $e^B_{(ij)kl}$ also was included in the model fitted based on our rules for selecting random effects. Its inclusion, however, did not affect the numerical values predicted for the design variables or any conclusions drawn from hypothesis tests.

Results

Weaning category

The lambs weaned at 10 weeks of age took varying lengths of time to reach their target weights at the 0·30 stage of maturity. During this time, the swards provided their only source of food. In contrast, lambs weaned at a weight, had access to their dam's milk until their 0·30 scanning. A consequence was that the lambs weaned at 10 weeks of age had a much lower level ($P < 0·001$) of fat in their carcass at the 0·30 stage of maturity than lambs that were both weaned and scanned at 0·30 of mature weight (Table 2). The lower level of fat led to associated increases in the contents of lean ($P < 0·001$) and bone ($P < 0·001$). However, by the 0·45 stage of maturity, there were no differences in carcass composition due to weaning category. The carcass gain of the lambs weaned at an age had a much higher fat content than that of the lambs weaned at a weight ($P < 0·001$; Table 3). The contents of lean and bone in the carcass gain were lower ($P < 0·05$). Although the rate of live-weight gain was not affected by weaning category, the rate of carcass gain was much higher ($P < 0·001$) in those weaned at an age than in those weaned at a weight: 62·11 *v.* 46·17 g/day (s.e.d. 3·29 g/day; Table 3).

Sex effects

The castrated male lambs had lower carcass fat and higher carcass lean contents at the 0·45 stage of maturity ($P < 0·05$; Table 2), and gained both live

Table 3 *Least-square means of average daily gains (g/day) in live weight, carcass weight and carcass fat, lean and bone weights, and the proportions of fat, lean and bone in the carcass-weight gain (g/kg), between the 0·30 and 0·45 stages of maturity by weaning criterion and by lamb sex*

	Weaning criterion by:			Lamb sex		
	Weight	Age	s.e.d.	Female	Castrate	s.e.d.
Average gain (g/day)						
Live weight	131·70	131·40	6·58	125·1	138·0	5·81*
Carcass weight	46·17	62·11	3·29***	51·26	57·03	2·90
Fat weight	13·84	23·98	1·24***	18·76	19·06	1·10
Lean weight	25·99	30·85	1·93*	26·05	30·79	1·70**
Bone weight	6·27	7·32	0·44*	6·44	7·16	0·39
Proportion in carcass gain (g/kg)						
Fat	262	380	23·2***	322	319	21·6
Lean	594	514	37·9*	563	546	34·7
Bone	144	106	19·6*	115	135	17·6

Table 4 *Least-square means for tissue proportions in the carcass by breed and sward at 0·45 stage of maturity. Proportions of tissues in carcass gain between 0·30 and 0·45 stages of maturity are also shown*

	Proportion of each tissue in carcass-weight gain (g/kg)			Tissue proportion at 0·45 maturity (g/kg)		
	Fat	Lean	Bone	Fat	Lean	Bone
Sward						
Ryegrass	310	591	98	186	633	182
Mixed	334	530	137	197	623	181
Clover	317	541	141	195	624	181
Max. s.e.d.	26·5	42·6	21·7	15·9	5·90	18·4
Breed						
Blackface	256	583	161	162	650	189
Cross	343	531	126	201	622	178
Suffolk	362	549	89	215	609	177
Max. s.e.d.	27·3	43·8	21·7	5·54	4·70	2·10
Significance†						
Breed	***		***	***	***	***

† The effects of Sward and Sward × breed interactions were not significant ($P > 0·05$).

weight and carcass lean at faster rates ($P < 0·05$ and $P < 0·01$ respectively; Table 3) than did the females.

Sward and breed type effects
There were no significant interactions between sward and breed type for either the proportion of the tissues in the carcass-weight gain or in the tissue proportions at the 0·45 stage of maturity. Therefore, only the main effects are considered (Table 4). As expected there were no effects of sward on carcass composition at the 0·30 stage of maturity (data not shown). There were also no effects of sward on the composition of the carcass gain although, as gain uses data from both scans, the standard errors were very large (Table 4). At the 0·45 stage of maturity there were no significant effects of sward on carcass composition (Table 4).

There were no significant effects of breed type on carcass lean or fat contents at the 0·30 stage of maturity. The Suffolk had higher bone content ($P < 0·001$) than did the Scottish Blackface, with the cross intermediate (data not shown). The carcass gain in the Scottish Blackface had higher bone and lower fat contents ($P < 0·001$) than did that of the Suffolk, with the cross in general intermediate but closer to the Suffolk for fat content (Table 4). As a consequence, the Scottish Blackface lambs had a lower carcass fat content, and higher lean and bone contents (all $P < 0·001$), at the 0·45 stage of maturity than did the Suffolk lambs. The values for the cross were intermediate but closer to those for the Suffolk.

There was a marked interaction between sward and breed type for the rates of gain of carcass and carcass fat weight ($P < 0·001$) and, to a lesser extent, bone weight and live weight ($P < 0·05$; Table 5). The Suffolk lambs grew significantly faster than the Scottish Blackface lambs on the clover swards but not on the ryegrass or mixed swards. The carcass gain was a smaller proportion of live-weight gain than would be expected from commercial dressing percentages. This was due, at least in part, to two contributory factors. Firstly the carcass weights were calculated as the sum of the weights of lean, fat and bone in the carcass excluding the kidney knob and channel fat, the kidney and the thoracic fat. Secondly the weights of the excluded tissues, as a proportion of the commercial carcass, increase as lambs grow (J. Macfarlane, unpublished).

The effects of the mixed sward on growth rates (Table 5) were similar to those of the ryegrass for all

Table 5 *Least-square means for average gains (g/day) in live weight (LW), carcass and carcass tissue weights between the 0·30 and 0·45 stages of maturity by breed × sward group*

		Average gain (g/day)				
Sward	Breed	LW	Carcass	Fat	Lean	Bone
Ryegrass	Blackface	92·7	31·4	8·86	17·82	4·71
	Cross	105·8	38·8	13·26	20·68	4·81
	Suffolk	92·7	38·8	15·09	19·92	3·77
Mixed	Blackface	84·9	26·0	7·12	14·68	4·15
	Cross	110·4	40·8	14·14	21·71	4·92
	Suffolk	93·6	36·4	14·07	18·23	4·07
Clover	Blackface	167·0	67·0	17·24	39·65	10·11
	Cross	221·5	100·6	37·57	50·99	11·98
	Suffolk	215·2	107·6	42·83	52·09	12·67
Max. s.e.d.		12·6	6·27	2·38	3·68	0·843
Significance						
Sward		***	***	***	***	***
Breed		***	***	***	***	
Breed × sward		*	***	***		*

breed types, as was to be expected from its low clover content (Table 1). Only on the clover did the Suffolk grow faster than the Scottish Blackface. Even on this sward it was not possible to distinguish between the Suffolk and the cross. The way in which the three breed types gained weight in the 10 weeks after the scan at the 0·30 stage of maturity on each of the three swards is shown in Figure 2a, b and c. Rates of gain are summarized in Figure 3.

Discussion

Weaning category

The weaning rule used in this study resulted in two groups of lambs that differed in several ways. Although the trial was not designed to explore the effect of weaning either at an age or a weight, this had important effects on lamb performance. It was necessary to account for this effect in the model used. A consequence of the weaning rule used was that lambs weaned at their target weight of 0·30 of mature weight were CT scanned for the first time having just been weaned. In contrast, the lambs weaned at 10 weeks had no access to milk in the period between weaning and being scanned at the 0·30 stage of maturity. As a result, the carcasses of the lambs weaned at 10 weeks of age had lower fat, and higher lean and bone, contents (Table 2). There was no difference in carcass composition between lambs of the two weaning groups at the 0·45 stage of maturity. This was because the lambs weaned at 10 weeks of age had a higher proportion of fat in their carcass gain (Table 3).

The lambs in the two weaning categories had similar average daily live-weight gain between the two scan points but lambs weaned at their target weight had slower rates of carcass tissue gain than those weaned at an age (Table 3). The difference is likely to be made up of growth in components of the digestive system and gut-fill. Lambs weaned at 10 weeks of age had grazed for some time (mean 36 (s.e. 2·6) days) before they were scanned at the 0·30 stage of maturity. Such lambs would be expected to have heavier guts and more gut-fill than lambs weaned at the target weight that had sucked up until their first scan. Therefore, between the scan points at the two stages of maturity, lambs weaned at the target weight would have had greater increases in weight of guts and gut contents than lambs weaned at an age. There is little relevant evidence to support this conjecture in sheep. However, in pigs, compensatory fattening has been observed together with changes in gut weight and gut-fill when the level of feeding was changed (Stamataris *et al.*, 1991).

The lack of any significant effects of either litter size at birth or rearing type agrees with the findings of Lewis *et al.* (2004b) and Macfarlane *et al.* (2004). In the present experiment any effect of litter size at birth or rearing type on early growth would have been subsumed, at least to some extent, in weaning category.

Sex effects

The female lambs were significantly fatter than castrated male lambs at the same weight (Table 2) in agreement with Kirton *et al.* (1982) and Wylie *et al.* (1997). The castrated male lambs in this study also grew faster in live and lean weights than the female lambs (Table 3) in agreement with Wylie *et al.* (1997). The proportional difference between the two sexes

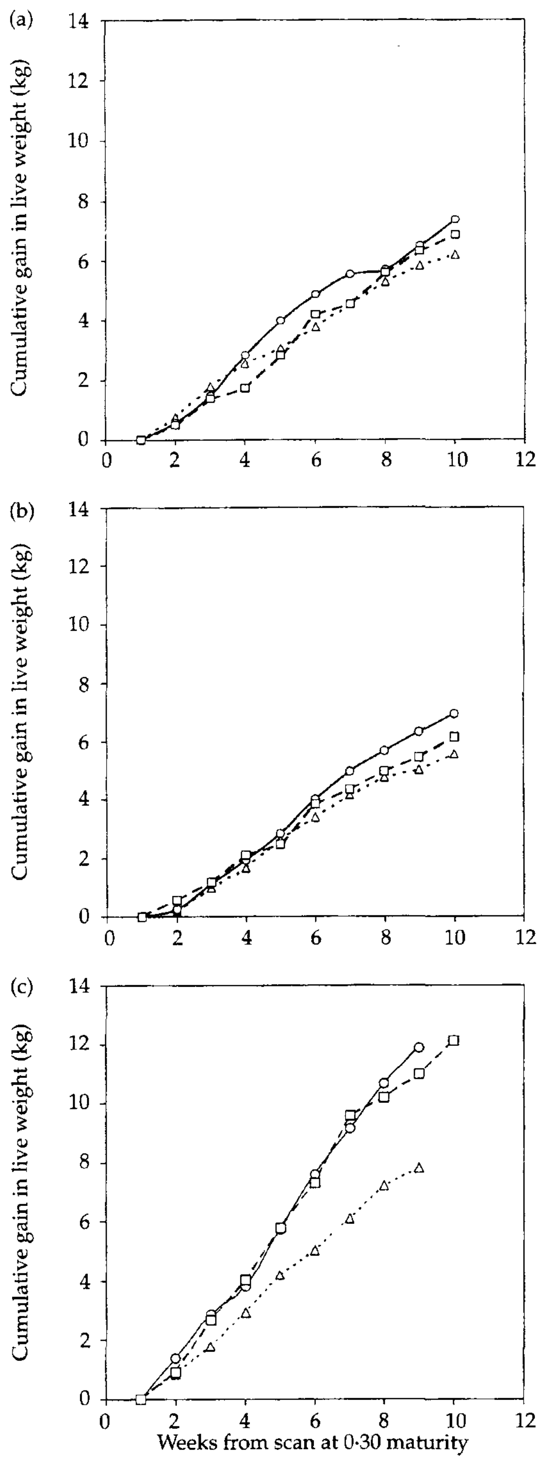

Figure 2 Cumulative weekly gains in live weight (kg) in the 10 weeks after the first computed tomography (CT) scan in Scottish Blackface (△), cross (○) and Suffolk (□) lambs on (a) the ryegrass sward, (b) the mixed sward and (c) the clover sward.

used here was smaller than that found between entire male and female lambs by Lewis *et al.* (2004b) and Macfarlane *et al.* (2004).

Breed type and sward effects

The Scottish Blackface lambs had a lower carcass fat content, and higher lean and bone contents, at the 0·45 stage of maturity than did the Suffolk lambs (Table 4). The values for the cross were intermediate but closer to those for the Suffolk. It is unusual to find differences among domestic breeds of sheep in carcass composition at the same degree of maturity (McClelland *et al.*, 1976; Taylor *et al.*, 1989).

Butterfield *et al.* (1983) found that the small difference in fatness between their two strains of Merino of different mature size was much reduced by comparison at an equal degree of maturity. In three Saudi Arabian sheep breeds, Gaili (1993) found no difference in carcass composition at an equal degree of maturity. Lewis *et al.* (2004b), using concentrate foods of different digestibility, and Macfarlane *et al.* (2004), using different dried and pelleted forages, also found no overall effects of breed type for carcass fat or lean contents. Both Lewis *et al.* (2004b) and Macfarlane *et al.* (2004) used the same breed types as used in this study and made their comparisons at equal degrees of maturity. Whether breeds are seen to differ in carcass composition at a degree of maturity therefore appears to depend on the nutritional environment. In finding a breed difference, our results here are the exception to the general findings as reported in the literature.

The grazing lambs used here, in agreement with those given dried forages (Macfarlane *et al.*, 2004), showed little overall effect of feeding on carcass composition and no breed type by feeding interactions were found. Even where widely different carcass compositions were produced in Suffolk sheep by using concentrate foods of different protein content (Lewis *et al.*, 2004a) or by using different levels of feeding (Lewis *et al.*, 2002), no genotype (line) by feeding interactions were found for either carcass fat or lean contents.

In contrast, when two concentrate foods of different digestibility were used, small yet significant interactions between genotype (Suffolk *v.* Scottish Blackface) and food were found for both carcass fat and lean contents (Lewis *et al.*, 2004b). The Suffolk lambs had a smaller increase in lean proportion, and a smaller decrease in fat proportion, on the less digestible food compared with the high quality concentrate, than did the Scottish Blackface. Although interactions between genotype and

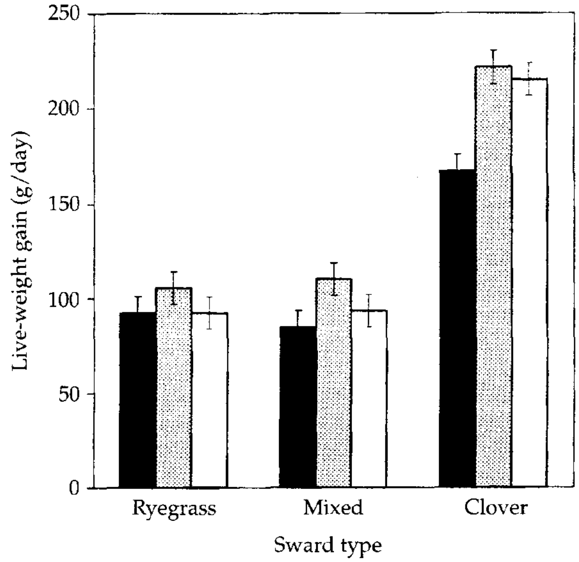

Figure 3 Least-square means of average daily gains in live weight (g/day) between 0·30 and 0·45 stages of maturity in the Scottish Blackface (■), cross (▩) and Suffolk (□) lambs grazing three swards. On the ryegrass and mixed swards there was no breed effect ($P > 0·1$); on clover, the Scottish Blackface grew slower than both the cross and the Suffolk ($P>0·001$).

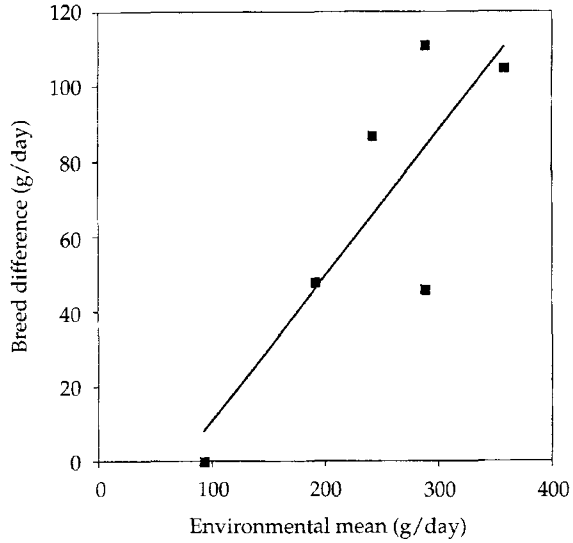

Figure 4 The environmental sensitivity of live-weight gain observed in six cases. Lambs of two sheep breeds, Scottish Blackface (B) and Suffolk (S), were kept in two nutritional environments in each of the experiments. The regression line shown is $Y = -27·9$ (s.e. 32·7) + 0·3869 (s.e. 0·127)X (R^2 = 0·643, residual s.d. 26·1 g/day), where Y is the breed difference (S-B) and X is the environmental mean.

environment for carcass composition in lambs have not been widely studied, there is some other evidence that such interactions may exist. In Merino-Branco and Merino-Branco × Ile de France lambs it was found that genotype differences in carcass muscle proportion were apparent only where concentrate feeding was used and not where the lambs were on pasture (Santos-Silva *et al.*, 2002).

The growth rates seen in the present experiment are similar to those seen in other grazing trials where Corriedale lambs grazed ryegrass (Montossie *et al.*, 2001) and Suffolk cross lambs out of Mule dams grazed clover-based swards (Vipond *et al.*, 1993). The breeds differed in their growth responses to the different swards. The Scottish Blackface had a significantly lower rate of growth than the Suffolk and cross only on clover (Figures 3 and 4). In this study, and in another where concentrate foods of different quality were given to the same breed types (Lewis *et al.*, 2004b), growth rates differed widely between foods, and a breed type by feeding interaction was found. In a further study, where lambs were offered different dried forages, or a choice between them, there were no large effects of feeding on growth rate and no breed type by feeding interaction was shown (Macfarlane *et al.*, 2004).

Lewis *et al.* (2002) found that a line of Suffolk sheep selected for lean growth rate was more sensitive in growth rate to level of feeding than was its unselected control. Such environmental sensitivity can be assessed by regressing a breed or line difference on the mean value across breeds or lines for an environment (Freeman, 1973; Jinks and Connolly, 1973; Falconer, 1989; Lewis *et al.*, 2002). For the cases described above, the regression of the difference in growth rate between Suffolk and Scottish Blackface lambs on the environmental mean is shown in Figure 4. The regression coefficient was greater than zero ($P < 0·05$) indicating that the extent to which growth rate in the Suffolk exceeded that in the Scottish Blackface decreased as the nutritional environment became poorer. The greater genetic potential for absolute growth rate in the Suffolk compared to the Scottish Blackface is thus fully expressed only in a better nutritional environment.

Despite the presence of an interaction between breed type and sward for growth rates, the overall effect of sward was such that growth rates were always higher for lambs grazing clover than either the ryegrass or the mixed sward. The lack of any significant differences in lamb performance between the ryegrass and mixed swards reflects their similar botanical composition (Table 1). The clover sward had higher protein content and was more digestible

(Table 1) and thus could be expected to be more nutritious. In addition, it is likely that these qualities will lead to higher levels of voluntary intake than ryegrass swards (McDonald *et al.*, 1995). It may be these characteristics that, at least in part, enabled the lambs on the clover sward to grow faster than those on the ryegrass sward.

Conclusions

In order to see the greater potential of breeds that are able to grow quickly the animals need to be given food appropriately. When animals are finished in a relatively poor nutritional environment, the potential differences in growth rate between breeds may be substantially reduced or may even disappear entirely. This paper has helped to quantify this effect for two common UK breeds and their cross in typical feeding environments. At the 0·45 stage of maturity, the sward that had been grazed did not affect carcass composition. Differences between breeds were present across the swards used, with the Scottish Blackface lambs having lower fat, and higher lean and bone contents, than either the Suffolk or the cross at the same degree of maturity in live weight.

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