
VOLUME 62 2002

Effect of slaughter group and sire on carcass composition and meat quality characteristics of Texel-sired lambs

P.L. JOHNSON, R.W. PURCHAS[1] and H.T. BLAIR

Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North, New Zealand

ABSTRACT

New Zealand meat companies are investigating lamb payment systems based on lean-meat yield and meat quality. Factors that affect these traits need to be determined. Carcass composition and meat quality data from 450 Texel-cross lambs (ewe and ram) were used to evaluate the effect of sire (two sires Property One, three sires Property Two) and slaughter group. Lambs reaching target slaughter weight first (38 kg and 35 kg for ram and ewe lambs respectively) were allocated to slaughter group one, with the remainder allocated to slaughter group two and slaughtered approximately 40 days later. The average carcass weight for both groups was 17.9 ± 1.51 kg. Carcass composition traits were adjusted for carcass weight, and meat quality traits were adjusted for pH. Carcass width at the thorax and gigot was narrower in slaughter group two ($P < 0.001$). Trimmed leg weight and total leg muscle weight were lower ($P < 0.001$), whereas total leg fat weight and muscle to bone ratios were higher ($P < 0.001$), for slaughter group two. Femur muscularity was higher in slaughter group two ($P < 0.001$) for Property One only. Warner-Bratzler shear values and measures of colour (L*, a* and b*) were higher ($P < 0.001$), whereas cooking loss was lower ($P < 0.001$), for the longissimus muscle in slaughter group two. In addition, sire within property was a source of variation ($P < 0.001$) for all carcass composition traits and meat quality traits, with the exception of pH. These results demonstrate that both slaughter group and sire (within a breed and property) are significant sources of variation in carcass composition and meat quality traits. As a result, these need to be taken into account when making management and breeding decisions for the supply of lambs to meat companies under any future payment systems based on yield and meat quality.

Keywords: lamb; carcass traits; sire.

INTRODUCTION

New Zealand meat companies are looking towards implementation of lean-meat-yield based payment for lamb carcasses together with an increased emphasis on meat quality. As a result progressive lamb producers are seeking information on ways to optimise returns when such systems are implemented. Information that is likely to be important include the effects of sex, time of slaughter, dam breed, sire breed and sire within breed on both the lean-meat yield and quality of the lamb meat produced.

Few studies have compared effect of time of slaughter on carcass traits at a relatively constant carcass weight, with most comparing traits over a time frame of at least four months. The most significant findings from these studies have been a decrease in meat tenderness with increasing age (Ellis *et al.,* 1997; Jeremiah *et al.,* 1998; Purchas *et al,.* 2002), although this has not always been the case (Kirton *et al.,* 1974)**.**

The majority of published work considering lamb carcass traits has compared sire breeds, as opposed to sires within a breed. However, results from a limited number of progeny tests and estimates of heritability suggest that differences do sometimes exist between progeny groups within a breed for certain carcass traits. Johnson *et al.* (2002) demonstrated significant differences in carcass value for a group of Romney sires. Fogarty (1995) reviewed heritability estimates for linear measures of carcass muscle and fat and showed that in general they are moderately heritable, which suggests a moderate level of genetic variation. Davidson *et al*. (2002) and Fogarty *et al.* (2003) using Merino populations are the only authors to have considered the heritability of meat quality traits in sheep. Results were inconsistent between the two studies, but in general the heritabilities for meat quality were lower than for carcass traits, suggesting less genetic variation or large environmental effects. Whether this is true in other breeds or for other important meat quality traits is, however, unknown.

The objective of the research reported here was to evaluate slaughter-group and sire (within breed) differences in lamb carcass composition and meat quality characteristics. The effect of sex has been addressed using the same data set by Johnson *et al*. (2005a).

[1] Institute of Food, Nutrition and Human Health, Massey University, Private Bag 11-222, Palmerston North, New Zealand

MATERIALS AND METHODS

Animals

The lambs in this study were generated as part of a trial searching for Quantitative Trait Loci (QTL) for carcass composition traits in the Texel breed. Ethical approval was obtained from the Animal Ethics Committee, Massey University, New Zealand, Protocol number 00/167.

Two Southland properties provided the lambs. On Property One, one Texel sire (Sire 1) and two Texel x Coopworth-cross sons of Sire 1 (Sires 2 and 3), were mated to Romney ewes. On Property Two, two half-sib Texel sires (Sires 4 and 5) were mated to Coopworth ewes. The lambs were born in the spring of 2001 and all lambs within a property were run together on pasture from birth until slaughter. Ram lambs were left entire and lambs were weaned at an average age of 71 days. The first slaughter group for each property included ram and ewe lambs that were at least 38 kg and 35 kg live weight. The rearing rank for lambs was either single or twin.

Experimental procedure

Lambs were weighed two days prior to slaughter to obtain a final live weight. They were trucked and held overnight prior to slaughter, which was the normal commercial procedure at Alliance's Smithfield processing plant in Timaru. Post-mortem treatment and chilling followed the New Zealand accelerated-conditioning and ageing standards (Chrystall *et al.,* 1989).

Measurements on the day of slaughter included soft tissue depth GR on both sides, carcass width at the widest part of the forequarter and at the narrowest point behind the shoulder, the maximum width of the hind legs (gigot width), and a carcass length from between the hind legs to the front of the neck (the lowest point on the hanging carcass). On the day following slaughter measurements of fat depth C, muscle depth B, and muscle width A were made on a cut between ribs 12 and 13 (*M. longissimus*) (Kadim *et al.,* 1989). The right leg was removed by a cut between the last and second-to-last lumbar vertebrae, and the right loin was obtained by a further cut between the last and second-to-last rib. These two portions were then loosely wrapped in plastic bags and frozen for one to five months at -18°C.

Frozen legs were thawed at ambient temperature (10 - 20°C) for approximately 18 hours prior to dissection into muscle, bone, subcutaneous fat, and intermuscular fat. In addition, the weight and length of the femur were recorded and five muscles around the femur (*Mm. semimembranosus, semitendinosus, biceps femoris, quadriceps femoris*, and *adductor)* were weighed, which enabled a muscle to bone ratio and muscularity value to be calculated (femur muscularity; Purchas *et al.,* 1991).

Meat quality was assessed for the *Mm. semimembranosus* and *longissimus*. Warner-Bratzler shear force was assessed following cooking of 25 mm steaks in a 70°C waterbath for 90 minutes (Purchas & Aungsupakron, 1993). Sarcomere length was determined using the laser diffraction method described by Cross et al. (1980 - 81). Samples were stored frozen before determination of colour and pH. Samples for colour analysis were prepared by thawing the samples at 0 - 1°C for approximately 18 hours and cutting them across the grain to expose a fresh surface to air in the chiller for 30 minutes prior to measuring colour using a Minolta ChromaMeter, calibrated to a white standard, using the L*, a*, b* scale. Ultimate pH was measured using a Sensorex spear-tip pH probe calibrated to pH 4 and 7 using buffer standards.

Statistical analysis

Data were analysed using the General Linear Model (GLM) procedure of SAS (SAS, 1991). Fixed effects of sex (ewe or ram), rearing rank (single or twin) and group (10 sire-group by slaughter-group combinations) were fitted for all models. A dissector effect (four people) was also fitted for dissection traits. Carcass weight or leg weight was fitted as a covariate when appropriate as indicated in the tables. pH was fitted as a covariate for meat quality traits. Interactions between the main effects were tested but were non-significant and were therefore not included in the final models. Comparisons were made between the first and second slaughter groups and between sires within a property (using contrasts).

RESULTS AND DISCUSSION

Approximately 88 progeny per sire were analysed (range 85 to 90 progeny), with 120 lambs in slaughter group one and 321 in slaughter group two. The average age of lambs in slaughter group one was 153 days (range 134 to 165 days) whilst for the second slaughter group it was 185 days (range 169 to 205 days). There were 24 single- and 96 twin-reared lambs in slaughter group one, and 39 single- and 282 twin-reared lambs in slaughter group two.

Effects of slaughter groups and of sire groups are reported for carcass traits (Table 1) dissection traits (Table 2) and meat quality traits (Table 3).

TABLE 1: Least-squares means for lamb carcass characteristics for groups (sire, slaughter group combinations), analysed to consider sire group effects and slaughter group effects. All variables except carcass weight were adjusted for carcass weight differences. The overall mean carcass weight was 17.9 kg.[1]

	CCW (kg)	DO%	LGWT (g)	CLNG (cm)	G (cm)	GR (mm)	C (mm)	A (mm)	B (mm)
Slaughter group effects									
Group 1 (n = 120)	17.1	41.3	2736.0	81.0	22.6	3.8	1.8	59.8	25.0
Group 2 (n = 321)	18.2	40.1	2655.0	80.3	22.0	5.9	2.3	58.1	25.7
Group 1 vs Group 2	***	***	***	**	***	***	***	***	*
Sire group effects									
Property One									
Sire 1 (n =89)	17.7	40.7	2719.8	80.6	22.5	4.4	1.6	59.9	25.6
Sire 2 (n=88)	16.7	40.0	2674.1	82.4	22.2	4.9	2.1	57.8	24.2
Sire 3 (n=85)	16.7	39.5	2672.7	80.8	22.3	4.4	2.0	58.2	24.7
Property Two									
Sire 4 (n=89)	18.0	41.1	2680.9	80.2	22.2	5.2	2.1	58.9	25.7
Sire 5 (n=90)	18.5	41.6	2723.5	80.0	22.4	5.1	2.2	59.6	26
Sire 1 vs (Sire 2 + Sire 3)	***	***	***	***	***	ns	***	***	***
Sire 2 vs Sire 3	ns	*	ns	***	ns	*	ns	ns	ns
Sire 4 vs Sire 5	*	*	**	ns	*	ns	ns	ns	ns
[RMSE]	1.32	1.57	92.77	1.70	0.53	1.58	0.73	3.49	2.09

[1] CCW: Ccrcass weight; DO%: dressing out percentage; LGWT: leg weight; CLNG: carcass length; G: width at the widest part of gigots; GR: fat depth at 12[th] rib; C: fat depth over B; A: *M. longissimus* width; B: *M. longissimus* depth
[2] ns: non-significant (P > 0.05); * P < 0.05; ** P < 0.01; *** P < 0.001

Slaughter group effects

Often at least two slaughter groups are required per property for lambs to reach target weights or condition scores (fat levels). Lambs will be in second and subsequent slaughter groups either because they were born later and/or because of slower growth rates (either due to differing mature weights or birth/rearing rank status). The effect of slaughter-group and/or age at slaughter is inconsistent, as results differ between studies because of the ages used and the effect of season on age, with most comparing young lambs (~ three months old) with lambs greater than one year old. The slaughter groups used for this trial, are likely to be more representative of a large proportion of the New Zealand sheep industry with all lambs slaughtered prior to winter.

Slaughter-group differences tended to be consistent between the two properties. Leg weight at a constant carcass weight was higher in the first slaughter group as was the width of the legs (G) and eye muscle width, but eye muscle depth was smaller (Table 1). Such differences have not previously been reported.

Measures of fat depth on the whole carcass (C and GR, Table 1) and total dissected leg fat weight were higher in slaughter-group two. A similar effect was shown by Bray *et al.* (1990) with increasing GR measurements between consecutive slaughters from February through May. However, the majority of studies that have compared lambs over a greater age range have not shown this trend, showing if anything a decrease in carcass fat (Purchas *et al.,* 2002). This supports the suggestion that weight-adjusted measures of fatness tend to increase as lambs approach the winter, but to decrease over winter and into the spring. Weight-adjusted carcass length was greater for Group 1, which is consistent with the lower level of fatness.

Total leg muscle weight was higher for the second slaughter group, which combined with a lower bone weight resulted in a higher muscle to bone ratio (Table 2). Such differences have not previously been reported. Muscularity in the femur region was similar for the two groups. Slaughter group effects were also evident for meat quality traits, with samples taken from slaughter-group two tending to be tougher, lighter (L*), and more intense in colour (higher a* and b*) (Table 3). The slaughter group effect on ultimate pH was not significant. The cooking loss (%) was slightly higher

TABLE 2: Least-squares means for lamb dissection characteristics for groups (sire, slaughter group combinations), analysed to consider sire group effects and slaughter group effects. All variables were adjusted for leg weight differences.

	LGMSWT (g)	LGFTWT (g)	LGBNWT (g)	FMLNG (mm)	MtoB	MUSC
Slaughter group effects						
Group 1 (n = 120)	1867	338	438	172.8	6.89	0.452
Group 2 (n = 321)	1894	350	404	172.4	7.31	0.456
Group 1 vs Group 2	***	**	***	ns	***	ns
Sire group effects						
Property One						
Sire 1 (n =89)	1880	344	423	170.1	7.01	0.463
Sire 2 (n=88)	1843	369	432	172.8	6.77	0.448
Sire 3 (n=85)	1837	362	447	174.0	6.41	0.441
Property Two						
Sire 4 (n=89)	1897	339	408	172.7	7.40	0.457
Sire 5 (n=90)	1918	321	408	173.0	7.54	0.458
Sire 1 vs (Sire 2 + Sire 3)	***	***	***	***	***	**
Sire 2 vs Sire 3	ns	ns	***	*	***	*
Sire 4 vs Sire 5	**	**	ns	ns	ns	ns
[RMSE]	48.3	45.7	24.5	3.74	0.479	0.050

[1]LGMSWT: leg muscle weight; LGFTWT: leg fat weight; LGBNWT: leg bone weight; FMLNG: femur length (mm); MtoB: muscle to bone ratio in the femur region; MUSC: muscularity in the femur region.
[2] ns: non-significant ($P > 0.05$); * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

for samples from the first slaughter group. These results are consistent with other studies in showing that meat quality of older lambs may sometimes be inferior to that of younger animals (Ellis *et al.,* 1997; Jeremiah *et al.,* 1998; Purchas *et al.,* 2002). However, this difference has not previously been demonstrated between such a short difference in slaughter times (6 weeks) as in the current study. Variation in slaughter weight, corresponded with variation seen in the weaning weight of the lambs. Multiple regression analysis indicated that the higher weaning weight of the first slaughter group was partly due to higher birth weights (5% of the variation) and greater age (20% of the variation), but mainly due to their faster growth rate (73% of the variation). This suggests that lambs of the second group were growing towards a lower mature weight and were therefore more mature when comparisons were made at the same weight, which helps to explain their greater fatness, higher muscle to bone ratio and more compact carcass.

Sire effects

The majority of farmers interested in improving carcass attribute place emphasis on choice of breed, and place comparatively little emphasis on the choice of sire within a breed. Likewise, most published papers have concentrated on breed comparisons, with limited consideration given to comparison of sires within a breed. Because of the trial design for the QTL study from which these data were taken, progeny numbers per sire and slaughter group were adequate to allow such an analysis.

Comparisons of sires within a property produced a number of significant results. Within Property One, comparisons between the pure Texel sire (Sire 1) and half-Texel sires (Sires 2 and 3) showed significant differences for all carcass and dissection traits with the exception of GR (Tables 1 and 2). The purebred Texel sired lambs had heavier carcasses and legs, higher dressing out percentages, shorter but wider carcasses and larger eye muscle areas, legs with more muscle, less fat and less bone, which equated to higher muscle to bone ratios and higher muscularity values. These findings are consistent with breed and yield comparisons involving Texels (Wolf *et al.,* 2001). However, there were no differences between the Texel sire and half-Texel sires for meat quality traits. A comparison of the progeny of the two half-Texel sires

(Sires 2 and 3), showed that progeny from Sire 2 had significantly higher dressing out percentages, longer carcasses and higher GR measurements. They also had significantly shorter and lighter femur bones which resulted in higher muscle to bone ratios and muscularity values. Differences were also detected for meat quality traits between these sires, with meat from progeny of Sire 3 being significantly less tender, and lighter in colour (L*), particularly for samples from the *M. longissimus* (Table 3). Within Property Two, two purebred half-sib Texels were used. Despite this common genetic base, significant differences were detected between the progeny groups for carcass weight, dressing out percentage, leg weight, carcass width at the thorax and gigot, leg muscle weight, leg fat weight and muscle to bone ratio, although there were no differences in meat quality.

This analysis has demonstrated that despite close genetic relations (half-sibs and parental) having been used, significant differences were observed in progeny from the different sires, although the differences tended to be more significant for carcass composition traits than for meat quality traits. This is consistent with estimates of heritability for linear measures of carcass traits which tend to be moderate to high (Fogarty, 1995), whilst those for meat quality traits tend to be lower (Davidson *et al.,* 2002 and Fogarty *et al.,* 2003).

The QTL study from which these data were taken has been successful in identifying a region of DNA which accounts for variation in the muscling and fat in the leg of Texels (Johnson *et al.,* 2005b). This in part explains some of the differences observed in this analysis as only half of the progeny from one of the sires from Property One are expected to be carrying the QTL as opposed to all of the progeny from the other sire, which explains the increased muscle and decreased fat. However, this QTL alone does not, explain many of the other differences observed as it has not been shown to affect carcass dimensions, leg bone, or *M. longissimus* traits.

TABLE 3: Least-squares means for lamb meat quality characteristics for groups (sire, slaughter group combinations), analysed to consider sire group effects and slaughter group effects.[1] All variables (excluding pH) were adjusted for pH.

	pHult	WBPK (kg)	WBYF (kg)	L*	a*	b*	SL (μm)	CL%
Slaughter group effects								
Group 1 (n = 120)	5.68	5.88	5.04	36.1	13.1	5.7	1.75	30.7
Group 2 (n = 321)	5.65	7.28	5.80	31.3	15.3	6.6	1.72	30.0
Group 1 vs Group 2	ns	***	***	***	***	***	ns	***
Sire group effects								
Property One								
Sire 1 (n =89)	5.75	6.07	4.83	33.3	14.0	5.9	1.72	30.2
Sire 2 (n=88)	5.67	5.52	4.73	34.1	14.1	6.3	1.72	30.0
Sire 3 (n=85)	5.68	6.66	5.42	32.6	14.1	5.9	17.4	30.2
Property Two								
Sire 4 (n=89)	5.63	6.89	5.71	34.3	14.4	6.4	1.74	30.8
Sire 5 (n=90)	5.64	7.27	5.98	33.8	14.2	6.3	1.74	30.4
Sire 1 vs (Sire 2 + Sire 3)	***	ns	ns	ns	ns	ns	ns	ns
Sire 2 vs Sire 3	ns	***	***	***	ns	**	ns	ns
Sire 4 vs Sire 5	ns	ns	ns	ns	ns	ns	ns	ns
[RMSE]	0.179	1.711	1.16	2.13	1.46	0.96	0.16	1.94

[1] pHult: ultimate pH; WBPK: Warner Bratzler peak force; WBYF: Warner Bratzler yield force; L* (colour lightness); a* (colour redness); b* (colour yellowness); SL: sarcomere length; CL%: cooking loss %

[2] ns: non-significant (P > 0.05); * P < 0.05; ** P < 0.01; *** P < 0.001

Implications for industry

The results of this study demonstrate that the effect of slaughter group is likely to be an important source of variation if new yield payment systems are introduced. Likewise when increased emphasis is placed on meat quality the effect of slaughter group will have increased importance.

An increased emphasis needs to be placed on selection of sires within a breed to optimise the carcass and meat quality attributes of lambs produced, as the results of this study demonstrate considerable between-sire differences (despite being close blood relatives) for important carcass and meat quality traits. The use of breeding values is the most accurate way that such genetic differences can be identified and these values should be used increasingly by farmers in their selection of sires in order to optimise returns.

ACKNOWLEDGEMENTS

Financial support for this project was provided by the C. Alma Baker Trust, Riverside Fund and personal support for the first author was provided by AGMARDT. The teams at Landcorp Farms, Mt Linton and AgResearch Woodlands provided the animals. The animals were processed at Alliance Smithfield. A. Machao, J.Blair, D. McGill and P. Salles carried out much of the dissection work and B. Purchas conducted most of the meat quality analysis.

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