

Carcass Traits in Relation to Genotype in Sheep

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ABSTRACT

Title: The effect of ...
Name: ...
Study leader: ...
Department: ...
University: ...
Degree: ...

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature :

Date:

ABSTRACT

Title: Carcass traits in relation to genotype in sheep.
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Degree: MSc (Agric.)

Experiment 1: Two studies were conducted to research the effect of divergent selection for multiple rearing ability on carcass weight, mutton production, meat quality and carcass characteristics of similar-aged Merino sheep. Data of 114 19-month-old Merino sheep, 40 ewes and 74 rams were used in this study. The study was done in two parts over 2 years. Only rams (52) were slaughtered over a two-week period in study A. Twenty-two rams and 40 ewes were slaughtered over a three-week period in study B. The sheep were descended from two selection lines that have been divergently selected for maternal multiple rearing ability since 1986. In brief, ewe and ram progeny of ewes rearing more than one lamb per joining (i.e. that reared twins at least once) were preferred as replacements in the high (H) line. Descendants of ewes that reared fewer than one lamb per joining (i.e. that were barren or lost all lambs born at least once) were preferred as replacements in the low (L) line. In study A the mean (\pm SE) slaughter weight of H line rams were 12% heavier ($P < 0.01$) than that of L line contemporaries. A corresponding difference ($P < 0.01$) of 13% was found for carcass weight. Adjustment for the higher live weight by analysis of covariance of H line rams resulted in most of the line differences being eliminated ($P > 0.05$). The difference between the weight of the loin retail cut remained significant ($P < 0.01$) in favour of the H line (1.64 ± 0.04 vs. 1.37 ± 0.08 kg, respectively). Skin weight (3.93 ± 0.15 vs. 3.34 ± 0.07 kg respectively; $P < 0.01$) and skin thickness (2.28 ± 0.11 vs. 1.97 ± 0.06 mm respectively; $P < 0.05$) were greater in L line rams than in H line contemporaries. Rams in the L line also had heavier ($P < 0.05$) trotters than the H line (1.05 ± 0.03 vs. 0.96 ± 0.02 kg respectively). In study B there were no interaction between line and sex and the data were pooled to present the main affects of sex and line. In study B the mean (\pm SE) slaughter weight of H line animals was 7% heavier ($P = 0.05$) than that of L line contemporaries (44.02 ± 0.7 vs. 41.2 ± 1.2 kg, respectively). A corresponding difference ($P < 0.05$) of 11% was found for carcass weight between the two lines (pooled sexes) (16.1 ± 0.3 vs. 14.4 ± 0.5 kg, respectively). There was no difference in the tenderness of the meat between the two

selection lines but L line animals tended ($P < 0.16$) to have more tender meat than H line contemporaries. Adjustment for the higher live weight of H line animals by analysis of covariance resulted in most of the line differences being eliminated ($P > 0.05$). Hindquarter weight still remained significantly ($P < 0.01$) in favour of the H line after correction for live weight. Meat of L line animals was healthier based on their PUFA/SFA ratio.

Experiment 2: This experiment was conducted to quantify the effect (noted in the first experiment) of selection for and against multiple rearing ability in Merino sheep on *m. longissimus dorsi* postmortem pH profiles. Data of 20 Merino sheep (10 rams and 10 ewes) were used. The sheep were slaughtered at a commercial abattoir. After slaughter pH was measured at 45 min, 2, 4, 8, 10, 12, 16, 20, 24, 33 and 48 h post slaughter, respectively. The pH was measured on the right side of each carcass in the *m. longissimus dorsi* between the 1st and the 6th lumbar vertebrae. The *m. longissimus dorsi* between the 1st and the 6th lumbar vertebrae of the left side was used for meat quality analysis. The initial pH of H line animals tended to be higher than that of L line contemporaries. At 48 h post-slaughter the pH of L line was higher ($P < 0.05$) compared to that of H line animals. The meat of H line animals was tougher (99.79 ± 3.58 vs. 88.32 ± 3.38 , $P < 0.05$) than that of L line contemporaries, but there were no differences in the other meat quality characteristics. A higher initial pH (found in the first experiment, with a similar tendency in the second experiment) could indicate a lower susceptibility to stress in the H line.

Experiment 3: An experiment was done to compare the meat-production potential between Merino and South African Mutton Merino (SAMM) ewes with increasing age. Slaughter data of 653 Merino and SAMM ewes were used. Animals were slaughtered between 220 and 2719 days of age, which encompassed a range of slaughter weights from 27 to 100 kg. The ewes were differentiated according to age, 219 ewes being younger than 600 days and 416 being older than 600 days at slaughter. Young SAMM ewes had 10% heavier carcass weights than young Merino ewes and the difference was 47% between mature ewes. Mean maximum carcass weights of 33.44 and 22.65 kg were derived for the SAMM and Merino, at respective age of 2100 and 1900 days. SAMM ewes had a 47% thicker fat depth. Although Merinos were earlier maturing than the SAMM ewes, the latter breed had more subcutaneous fat at the mature stage.

Experiment 4: The fourth experiment examined the effect of breed and sex on the carcass composition, yield of retail cuts, fat depth and chemical composition of meat from 35 South African Mutton Merino (SAMM) (17 rams and 18 ewes) and 61 Dormer (21 rams and 40 ewes) sheep. As there was no breed x sex interaction, the data were pooled to present the main effects of breed and sex. There were no differences in slaughter and carcass weight between Dormer and SAMM sheep. Dormers' had more fat (kidney, back fat depth) than SAMM sheep. The eye-muscle area of the

Dormers' was 13% larger than that of the SAMM sheep. Rams were heavier (64.86 ± 0.85 vs. 44.55 ± 0.74 kg) than the ewes at slaughter. All the traits that were recorded, were heavier or higher in rams ($P < 0.05$). After adjustment for higher live weight of the rams, the proportion of neck retail cut from the rams was higher than that from ewes and the proportion of hindquarter weight from the ewes was higher ($P < 0.05$) than that from rams. After adjustment for the higher live weight of the rams, the moisture (75.35 ± 0.37 and $73.35 \pm 0.37\%$) and lipid (2.68 ± 0.33 and $3.80 \pm 0.33\%$) contents differed significantly ($P < 0.05$) between the rams and ewes, respectively. With the significantly higher SFA value of the SAMM sheep and higher MUFA value of the Dormer sheep, meat from Dormer sheep could be regarded as healthier from a human prospective than that from SAMM sheep.

Experiment 5: A study was done to test an ultrasound scanner (used on pigs) for the prediction of subcutaneous backfat and *m. longissimus dorsi* depth on Merino (52 rams), SA Mutton Merino (17 rams and 18 ewes) and Dormer (21 rams and 40 ewes) sheep. The sheep were scanned with an ultrasound scanner to predict the backfat and eye-muscle depth on the live animal. All animals were slaughtered to measure the true values of the fat depth and eye-muscle depth (25 and 45mm from the midline at the 13th rib). Overall regression equations over breeds (SAMM and Dormer, pooled breeds), and lines (H and L line Merinos, pooled lines) were obtained. Compared to previous research, the correlations between scanned values and true values were comparatively low ($r = 0.07 - 0.25$). Evidence from the literature suggested higher correlations of $r = 0.53 - 0.56$. Higher correlations could be achieved in older and fatter animals. The fact that the operator had no experience of scanning sheep could also have contributed to the low correlations.

OPSOMMING

Titel : Karkas- en vleiseienskappe in verskillende skaap genotipes.
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Eksperiment 1: Twee studies is gedoen om te kyk na die invloed van seleksie vir meerling grootmaakvermoë by Merino's op karkas-, vleiseienskappe en vleiskwaliteit is. Data van 114 19 maand oue Merino skaap, 40 ooie en 74 ramme is in die studie gebruik. Die studie is gedoen in twee dele oor 'n tydperk van twee jaar. Slegs ramme (52) is geslag oor 'n tydperk van twee weke in studie A. Twee en twintig ramme en 40 ooie is in studie B geslag oor 'n periode van drie weke. Merino-ooie en -ramme afkomstig van 'n hoë (H-lyn) en lae (L-lyn) lyn geselekteer vir meerling grootmaakvermoë is gebruik in 'n studie wat oor twee jaar uitgevoer is. Die twee lyne is intensief geselekteer vir en teen meerling grootmaakvermoë vanaf 1986. Ram- en ooi-nageslag wat afkomstig is van ooie wat een of meer keer tweeling in haar lewe per lam kans groot gemaak het is gebruik vir die H-lyn, terwyl ram en ooi nageslag afkomstig van ooie wat een of minder as een lam per lamkans groot gemaak het is gebruik vir die L-lyn. In studie A is 52 ramme (42 H-lyn en 10 L-lyn) geslag en slag- en karkaseienskappe is bestudeer. In ondersoek B is 22 ramme (16 H-lyn en 6 L-lyn) en 40 ooie (34 H-lyn en 7 L-lyn) gebruik. Slag-, karkas- en vleiseienskappe is bestudeer. In ondersoek A is gevind dat die slagmassa van die H-lyn ramme 12% hoër en die karkasmassa 13% hoër is as die van die L-lyn ramme. Na kovariansie ontleding van die swaarder slagmassa van die H-lyn diere, was die pote (1.05 ± 0.03 vs. 0.96 ± 0.02 kg; $P < 0.05$) en velle swaarder (3.93 ± 0.15 vs. 3.34 ± 0.07 kg; $P < 0.01$) en die velle dikker (2.28 ± 0.11 vs. 1.97 ± 0.06 mm; $P < 0.05$) by L-lyn diere as by H-lyn diere. Die groothandel lende snit van die H-lyn diere was swaarder (1.64 ± 0.04 vs. 1.37 ± 0.08 kg; $P < 0.05$) as die van L-lyn diere. By studie B was daar geen interaksie tussen lyn en geslag nie, dus is die data verpoel om die betekenisvolheid van die hoofeffekte van lyn en geslag weer te gee. 'n Sewe persent hoër slagmassa is by H-lyn diere waargeneem (44.02 ± 0.7 vs. 41.20 ± 1.2 kg; $P < 0.05$). 'n Ooreenstemmende verskil van ($P < 0.05$) 11% is gevind in karkas massa tussen die twee lyne (16.1 ± 0.3 vs. 14.4 ± 0.5 kg). Daar was geen verskil in taatheid van die vleis nie, maar diere van die H lyn se vleis het geneig ($P < 0.06$) om taaier te wees. Na die kovariansie

ontleding met massa as kovariant was die boude ($P < 0.01$) van die H-lyn diere en die lende ($P < 0.01$) groothandel snit van die ooie swaarder, verder was die verskille dieselfde as in ondersoek A. Die vetsuurresultate toon dat net by die verhouding tussen die poli-onversadigde en versadigde vetsure (PUFA/SFA) 'n verskil tussen die lyne was. Die vetsuur resultate dui daarop dat die L lyn diere gesonder vleis vir menslike voeding het as die van die H lyn diere.

Eksperiment 2: In 'n tweede eksperiment is gekyk wat die invloed van seleksie vir meerling grootmaakvermoë by Merino skape op *post mortem m. longissimus dorsi* pH profiele is. Daar is gebruik gemaak van 20 Merino skape (10 ooie en 10 ramme), 10 H lyn en 10 L lyn diere. Die skape is geslag by 'n kommersiële abattoir. Die pH metings is geneem, 45 min, 2, 4, 6, 8, 10, 12, 16, 20, 24, 33 en 48 uur na slag. Die pH is geneem in die *m. longissimus dorsi* van die regter sy tussen die 1^{ste} en 6^{de} lumbale werwels. Die linker kant is gebruik vir vleiskwaliteits toetse. Die pH lesing van H lyn diere wat 45 min na slagting geneem is het hoër geneig as in L lyn, terwyl pH lesings van die L lyn diere 48 h na slagting hoër was. Die vleis van die H lyn diere was taaier (99.79 ± 3.58 vs. 88.32 ± 3.38 ; $P < 0.05$) as die van die L lyn diere, maar daar was geen verskille in die ander vleiskwaliteits toetse nie. Die hoë begin pH kan daarop dui dat die H lyn skape minder spanning voor slag ervaar het.

Eksperiment 3: Die invloed van ouderdom op vleis produksie potensiaal, slag en karkasmassa en vetdikte by Suid Afrikaanse Vleis Merino (SAVM) en Merino ooie is ondersoek. Data van 635 Merino en SAVM ooie is gebruik. Die ooie was tussen 220 en 2719 dae oud met slagting en slagmassas wat gewissel het tussen 27 en 100 kg. Die ooie is opgedeel ten opsigte van ouderdom. Die jong groep was ooie wat jonger as 600 dae oud was en die ouer was bestempel as die ou groep. Die karkas massa van die jong SAVM ooie was 10% hoër as die van die Merino ooie en by die ou groep was die verskil 47%. Ouer SAVM ooie het 52% dikker vet as die Merino ooie gehad. Merino ooie het 'n maksimum karkas massa van 22.65 kg op 'n ouderdom van 1900 dae gehad terwyl SAVM ooie 'n maksimum karkas massa van 33.44 kg op 'n ouderdom van 2100 dae gehad het. Al is die Merino 'n vroër ryp skaap as die SAVM, het die SAVM meer vet as volwasse dier.

Eksperiment 4: In die experiment is gekyk na die effek van ras en geslag op slagmassa, karkasmassa, vleiseienskappe asook chemiese en vetsuur samestelling van die vleis van SAVM en Dormer skape. Slagdata van 61 Dormers' (21 ramme en 40 ooie) en 35 SAVM's (17 ramme en 18 ooie) is gebruik. Daar was geen interaksie tussen ras en geslag nie en dus is die data verpoel om die invloed van die hoof effekte (ras en geslag) te toets. Geen verskille is in die slagmassa tussen die Dormers en SAVM gevind nie. Die vet (onderhuids en niervet) van die Dormers was meer en die oogspier oppervlakte was 13% groter as die van SAVM skape. Ramme was swaarder (64.86 ± 0.85

vs. 44.55 ± 0.74 kg) as die ooie met slag. Na kovariansie ontleding van swaarder slagmassa van die ramme was die groothandel nek snit van die ramme swaarder ($P < 0.05$) as die van die ooie en die boude van die ooie swaarder ($P < 0.01$) in vergelyking met die van die ramme. Die voginhoud van vleis vanaf ramme was hoër (77.35 ± 0.37 vs 75.35 ± 0.37) as die van die ooie. Ooie het 'n hoër persentasie vet in die vleis van die 11/13de ribsnit gehad (2.68 ± 0.33 vs. 3.80 ± 0.33 %). Volgens die vetsuur analyses het SAVM diere 'n hoër persentasie versadigde vetsure en die Dormers 'n groter persentasie mono-onversadigde vetsure gehad. Dit kan 'n aanduiding wees dat vleis vanaf Dormer skape gesonder is vir menslike gebruik.

Eksperiment 5: Hierdie studie is gedoen om 'n ultraklank apparaat (gebruik by varke) te toets vir voorspelling van onderhuidse vet en oogspierdiepte by skape. Daar is gebruik gemaak van 52 Merino ramme (42 van die H-lyn en 10 van die L lyn), 61 Dormer skape (21 ramme en 40 ooie) en 35 SAVM skape (17 ramme en 18 ooie). Die vetdikte en oogspierdiepte op die lewende diere is bepaal met 'n ultraklank apparaat, waarna die diere geslag is en die werklike waardes direk op die koue karkas gemeet is. Regressie vergelykings is opgestel om korrelasies tussen ultraklank waardes en werklike waardes te kry. In hierdie proef was die korrelasies tussen geskatte en werklike waardes swak ($r = 0.07-0.25$). Beter korrelasies is egter wel deur ander navorsers gekry ($r = 0.53-0.56$). Beter korrelasies kan in ouer en vetter diere verkry word. Die feit dat die operateur nie baie ondervinding met die skandering van skape gehad het nie kon bydrae tot die swak korrelasies.

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Language and style in this thesis are in accordance with requirements of the *South African Journal of Animal Science*. This thesis represents a compilation of manuscripts; each chapter is an individual entity and some repetition between chapters is therefore unavoidable.

Chapter 1

GENERAL INTRODUCTION

Breeds of sheep have always been selected to produce more meat and/or wool, to produce better quality products and to survive in particular environments. This still continues today within changing markets and the increasing need to improve efficiency of production and productivity (Fogarty, 1983). The most important components of ewe productivity are the total weight of lamb produced, body weight at culling, and in the case of wool-producing sheep, the quantity and quality (mainly fibre diameter) of the wool (Olivier, 1999; Hoon *et al.*, 2000). Breeds are developed, amongst other things, to:

- increase lamb production per ewe;
- increase flexibility of lambing time;
- allow economical intensification of lamb production;
- increase growth rate and feed efficiency;
- reduce carcass fat content and/or change carcass fat distribution;

It is very difficult to combine all these desirable traits for the production of lamb at optimum levels in any breed (Fogarty, 1983).

The major energy cost in lamb production is associated with maintenance of the ewe flock and replacement females. Considerable improvement in efficiency can be achieved by increasing the total weight of lamb per ewe joined per year (Fogarty, *et al.*, 2000). This can be achieved by increasing litter size weaned and/or lambing frequency and an earlier age at first joining. Ewes with the potential for a higher lambing rate and year round joining ability, suited to intensive production and capable of being exploited for cumulative genetic improvement is urgently required (Fogarty *et al.*, 2000). Nurture of the young is almost completely the responsibility of the female in mammalian livestock species and maternal performance is conveniently measured as a component of offspring performance. Maternal effects arise from the effects of uterine environment on birth weight and the effects of milk production on preweaning growth (Notter, 1987).

Improvements in efficiency can also be achieved by increased lamb growth rate and changes in carcass composition. Until recent years lamb (meat) production has been largely a by-product of the wool industry. From 65 to 88% of the total income from wool sheep is presently derived from mutton, while it is even higher in the case of mutton sheep (Hoon *et al.*, 2000). Production of heavier and leaner carcasses reduces costs and provides a more acceptable product to the consumer (Fogarty, 1983). Lean muscle and to a lesser extent fat are the major edible tissues of the carcass.

In countries where meat is sold in cuts, the lean content of each cut is an important factor in determining its value. Amount and location of fat in the carcass influence its quality (Mahgoub & Lodge, 1998). Linked to this is the effect of the environment. With the low rainfall in most parts of South Africa, extensive production systems are practiced. Thus lambs are often slaughtered at 10-12 months of age. South Africa has a climate that lends itself better to fine wool production than to lamb production.

In South Africa there are 25 million sheep and two of the most popular sheep breeds in South Africa are the SA Mutton Merino (SAMM) and Merino sheep (Campher *et al.*, 1998). The SAMM is a dual-purpose (mutton and wool) sheep breed that was developed from the imported German Merino, which has a high growth rate and produces a lamb suitable for slaughter at an early age with good meat characteristics (Neser *et al.*, 2000). The average lambing percentage of the breed is estimated at 150%. The average wool production of mature rams is 4.5-6 kg and those of the ewes 3.4-4.5 kg with a mean diameter of 22-23 micron (Campher *et al.*, 1998).

The Merino is a wool-type sheep that originated from Europe. Merino sheep compose 40% of the total sheep population in South Africa. The lambing percentage of the Merino is between 75 and 120%. Merinos produce 3-6 kg wool. The potential of Merinos for producing wool is unique, it is the only sheep in the world that can produce 10-15% of its own live mass in clean wool (Campher *et al.*, 1998). There are different strains of Merinos (as classified according to wool quality characteristics), which may vary from strong wool (25 micron) to the finest wool (16 micron), and from a plain bodied sheep to more developed sheep (Campher *et al.*, 1998).

The Dormer breed was developed on the Elsenburg experimental farm from crosses between the Dorset Horn and German Mutton Merino breeds and is also a dual-purpose (mutton and wool) sheep breed (Van der Merwe, 1976). The principal objective with the development of the Dormer was to provide a terminal sire breed for crossbreeding on Merino ewes (Van der Merwe, 1976). A lambing percentage of 120-150% is common in Dormer sheep (Campher *et al.*, 1998).

When animals develop, a principal wave of growth begins at the head and spreads down the trunk, secondary waves start at the extremities of the limbs and pass upwards. All these waves meet at the junction of the loin and the last rib, which is the last region to develop. With an increase in live weight, intermuscular fat and subcutaneous fat content increase (Lawrie, 1998). The average mature live weights of SAMM rams are 127 kg and those of the ewes 77 kg (Campher *et al.*, 1998). Merino rams weight 90 kg at maturity and ewes 45-65kg (Campher *et al.*, 1998). The average mature live weight of Dormer ewes is 76 kg and that of rams 125 kg (Campher *et al.*, 1998).

Differences between breeds occur because of the difference in growth rates between breeds. SAMM sheep have a preweaning growth rate of 245 g/day for rams and 223 g/day for ewes.

Dorper sheep achieved a preweaning growth rate of 275 g/day and 272 g/day for rams and ewes, respectively and the Merino an average preweaning growth rate of 196 g/day for rams and ewes (Campher *et al.*, 1998). Early-maturing animals reach maximum potential for fat growth at a younger and lighter live mass than late-maturing animals (Lawrie 1998). The Dorper is an early-maturing breed and tends to gain fat easily. The SAMM sheep is a late-maturing breed which does not gain fat easily (Neser *et al.*, 2000).

Ram lambs grow more rapidly than either castrated males or females. In most studies the superior growth rate of rams has been observed from birth through to maturity (Wylie *et al.*, 1997). Despite the difference in growth rate, at equal slaughter weight rams yield lower carcass weights than do either castrated males or female lambs due to heavier head weights and the weight of the testes (Purchas, 1978). There is almost no differences in the muscle distribution between different sheep breeds (Lawrie, 1998). The percentages of carcass mass distribution in SAMM and Merino sheep are shown in Table 1 (Casey, 1982).

Table 1. Percentage carcass mass distribution in SAMM and Merino sheep (Casey, 1982).

Breed	Slaughter mass (kg)	Fore Limb (%)	Neck (%)	Ventral Trunk (%)	Dorsal Trunk (%)	Hind Limb (%)
SAMM	10	18.11	9.87	15.10	19.70	37.22
	23	16.28	7.85	20.84	20.31	34.72
	32	15.12	7.78	23.21	20.85	33.04
	41	14.82	7.84	24.37	21.53	31.44
	avg.	16.08	8.33	20.88	20.60	34.11
Merino	10	18.05	9.86	18.09	20.28	33.72
	23	16.03	8.93	23.10	20.76	31.2
	32	15.02	7.99	24.32	21.27	31.14
	41	14.95	8.32	25.96	20.85	29.92
	avg.	16.01	8.78	22.87	20.73	21.56

Ram lambs exhibit several desirable characteristics, depositing less overall carcass fat, and having smaller individual fat depots, than ewes (Kirton *et al.*, 1982). Because the carcass fat content increases as live weight increases, carcass fat content is the principal determinant of an optimum slaughter weight. Accordingly, the lower proportion of carcass fat in rams should favour the slaughter of ram lambs at heavier weights. At equal levels of carcass fat the slaughter weight advantages of rams over wethers, and of wethers over ewes, has been estimated at 3 and 2 kg,

respectively. Ram lambs are thus usually confined to production systems which promote faster growth rates with target slaughter dates before puberty but, where management problems can be overcome, rams could provide both a higher growth rate over an extended period and a reduced carcass fat content. Progress towards achieving higher lamb carcass weights, irrespective of sex, whilst retaining lower levels of carcass fat (in line with the current consumer demand for leaner meat), is likely to require breeds with naturally higher carcass lean content (Wylie *et al.*, 1997).

With the onset of sexual maturity further differential muscular development occurs whereby, in the male, muscles of the head, neck and thorax grow relatively fast (Jeremiah *et al.*, 1997), whilst the hindquarters of the ewes develop at a faster rate (Fahmy *et al.*, 1999). In most species of domestic animals, although the female matures earlier, the male is larger and heavier than the female in adult life (Lawrie, 1998).

There is evidence to show that consumers demand leaner cuts of lamb. If sheep meat is to hold or extend its market share, fat content has to be reduced. The development of boneless lamb cuts, low in fat and high in lean meat, is aimed at meeting these consumer requirements (Gilmour *et al.*, 1994). Live weight variation was regarded as a major problem affecting the marketability of slaughter lambs. Development of carcass merit pricing systems requires the use of objective technology for assessing carcass composition or lean distribution. Accurate objective evaluation of yield grade could sufficiently identify differences in carcass composition and could conceivably be the basis for lamb carcass pricing. Even using the most experienced subjective evaluators, this single-point parameter is still a marginal predictor of lamb carcass composition (Berg *et al.*, 1997).

Many experiments measuring carcass fat components have indicated that most, if not all fat components, show genetic variation (Botkin *et al.*, 1969; Wolf *et al.*, 1981; Bennit *et al.*, 1998). Breeding programmes have thus been proposed as a means of reducing fat content. Different ultrasound technologies to measure fat depth over the *m. longissimus dorsi* at the 12th rib have been applied successfully in sheep breeding research programmes to alter carcass composition (Gooden *et al.*, 1980). The advantage of ultrasonic technology over other proposed methods is the lower cost of machinery and it has been successfully applied in the pig-breeding industry (McEwan *et al.*, 1993).

Two different types of ultrasound scanners may be used. The first type of scanner produces a one-dimensional profile of the tissue, which is ideal for measuring the depth of the fat/muscle interface. The other type of scanner produces a two-dimensional image to outline the eye-muscle (*m. longissimus dorsi*) area, although the resolution of interface perpendicular to the skin is generally poor (Gilmour *et al.*, 1994). A very experienced operator must take ultrasonic recordings, using this system.

Growth rate is a very important factor in a lamb production system. The dramatic increase in muscularity and decrease in fatness resulting from the callipyge gene offer tremendous potential for the lamb industry, provided that a solution can be found to the gene's unwanted effect on meat toughness (Meyer *et al.*, 1998).

It has been shown that muscle pH, which is a measure of glycolysis, can range from 6.85 to 6.05 in lamb carcasses post-mortem (McGeehin *et al.*, 2001). There are several factors affecting the rate of muscle pH decline: stress (Apple *et al.*, 1995), electrical stimulation (Chrystall *et al.*, 1984) and chilling temperature (Bowling *et al.*, 1978) being factors that have been investigated. But these factors do not account for all the variation between animals that occurs during post mortem muscle pH decline. Animal factors such as sex, species, breed and age as well as extensive factors such as season also have an effect (McGeehin *et al.*, 2001).

Meat tenderness is linked to the rate of muscle pH decline. If the muscle pH is too high in the early hours post mortem, cold shortening may occur when the carcass temperature is lowered too quickly, causing the meat to toughen (Lawry, 1998). Electrical stimulation (ES) can be used to bring about a rapid reduction in pH, thus avoiding the possibility of cold shortening. A potential problem exists if ES is applied to carcasses with a naturally fast rate of pH fall. Abril *et al.* (2001) have shown that the pH of already fast glycolysing carcasses can be lowered too quickly, resulting in a decline in meat tenderness. Maximum tenderness of meat is associated with an intermediate rate of glycolysis and not the high rate often obtained using electrical stimulation (Chrystall *et al.*, 1984).

Increased lamb production per ewe is very important. The effect on reproduction due to the presence of the Booroola gene has been studied widely (Metherell, 1984; Ponzoni *et al.* 1985; Bradford & Quirke, 1986; Visscher *et al.*, 2000). Visscher *et al.* (2000) found that Merino crosses carrying one or more than one copy of the Booroola gene had relatively bigger and fatter carcasses compared to their contemporaries without the gene.

In a broad sense the composition of meat can be approximated at 75 percent moisture, 19 percent protein, 3.5 percent of soluble, non-protein, substances and 2.5 percent of fat (Lawrie, 1998). In Table 2 the proximate analysis of lamb meat can be seen (USDA, 2001)

Table 2. The proximate analysis of lamb meat (USDA, 2001).

Characteristic	Value per 100 grams of edible portion
Moisture (g)	60.7
Protein (g)	16.88
Total lipid (g)	21.59
Ash (g)	0.88

Fat content of meat is very important and fatty acids are the most important lipid fraction. They have a particular role in the immune function, prevention of inflammation and as energy source (Wan *et al.*, 1989). The degree of saturation of the fatty acids is one of the most important characteristics affecting lipid quality. Saturated fats solidify easily upon cooling and increase the hardness of the fat, thus affecting the palatability of the meat and consumer acceptability (Webb *et al.*, 1994). However, less saturated fat is known to oxidise, leading to rancidity and a concomitant decrease in shelf-life (Casey & Van Niekerk, 1985). It is generally accepted that cholesterol concentration in humans is influenced by the fatty acid composition of dietary fat. High dietary levels of long-chain, saturated fatty acids (SFA) increase plasma cholesterol levels in humans compared with high levels of mono-unsaturated fatty acids (MUFA), while polyunsaturated fatty acids (PUFA), on the other hand, do not have this effect (Grundy & Denke, 1990). However, not all SFA have the same effects. Lauric acid (C12:0), myristic acid (C14:0) and palmitic acid (C16:0) raise plasma cholesterol levels (Denke & Grundy, 1992), whereas stearic acid (18:0) has no effect (Grundy & Denke, 1990). The fatty acid composition of raw lamb meat is summarized in Table 3 (USDA, 2001).

Table 3. Fatty acid composition of lamb meat (USDA, 2001).

Nutrient	Value per 100 grams of edible portion of lamb meat
Saturated fatty acids (g)	9.470
10:0	0.060
12:0	0.100
14:0	0.870
16:0	4.750
18:0	2.980
Mono-unsaturated fatty acids (g)	8.860
16:1	0.630
18:1	7.960
Polyunsaturated fatty acids (g)	1.700
18:2	1.240
18:3	0.390
20:4	0.070

REFERENCES

- Abril, M., Campo, M.M., Önenç, A., Sañudo, C., Albertí, P. & Negueruela, A.I., 2001. Beef colour evolution as a function of ultimate pH. *Meat Sci.* 58, 69-78.
- Apple, J.K., Dikeman, M.E., Minton, J.E., McMurphy, R.M., Fedde, M.R., Leith, D.E. & Unruh, J.A., 1995. Effects of restraint and isolation stress and epidural blockade on endocrine and blood metabolite status, muscle glycogen metabolism, and incidence of dark-cutting longissimus muscle of sheep. *J. Anim. Sci.* 73, 2295-2307.
- Bennit, G.L., Meyer, H.H. & Kirton, A.H., 1998. Genetic and environmental effects on carcass characteristics of Southdown x Romney lambs: 1. Growth rate, sex, and rearing effects. *J. Anim. Sci.* 69, 1856-1863.
- Berg, E.P., Neary, M.K., Forrest, J.C. & Thomas, D.L., 1997. Evaluation of electronic technology to assess lamb carcass composition. *J. Anim. Sci.* 75, 2433-2440.
- Botkin, M.P., Field, R.A., Riley, M.L., Nolan, J.C. & Roehrkaase, G.P., 1969. Heritability of carcass traits in lambs. *J. Anim. Sci.* 29, 251-255.
- Bowling, R.A., Smith, G.C., Dutson, T.R. & Carpenter, Z.L., 1978. Effects of pre-rigor conditioning treatments on lamb muscle shortening, pH and ATP. *J. Food Sci.* 43, 502-507.

- Bradford, G.E. & Quirke, J.F., 1986. Ovulation rate and litter size of Barbados Targhee and crossbred ewes. *J. Anim.Sci.* 62, 905-909.
- Campher, J.P., Hulun, C. & Van Zyl, G.J., 1998. South African Livestock Breeding. South African Stud Book and Livestock Improvement Association. PO Box 270. Bloemfontein 9300, South Africa.
- Casey, N.H., 1982. Carcass and growth characteristics of four South African sheep breeds and the Boer goat. Ph. D. Thesis. University of Pretoria, South Africa.
- Casey, N.H. & Van Niekerk, W.A., 1985. Fatty acid composition of subcutaneous and kidney fat depots of Boer goats and the response to varying levels of maize meal. *S. Afr. J. Anim. Sci.* 15 (2), 60-63.
- Chrystall, B.B., Devine, C.E., Ellery, S. & Wade, L., 1984. Low voltage electrical stimulation of lamb: its effect on muscle pH and tenderness. *N. Z. J. Agric. Res.* 27, 513-523.
- Denke, M.A. & Grundy, S.M., 1992. Comparison of effects of lauric acid and palmitic acid on plasma lipids. *Anim. J. Clin. Nutr.* 56, 895-898.
- Fahmy, M.H., Garipey, C. & Fortin, J., 1999. Carcass quality of crossbred lambs expressing the callipyge phenotype born to Romanov purebred and crossbred ewes. *Anim. Sci.* 69, 525- 533.
- Fogarty, N.M., 1983. Development of new breeds for meat production. Proc. National Workshop "Implications of developments in meat science, production and marketing for lamb production systems." Paper 26, 1-6.
- Fogarty, N.M., Hokins, D.L. & Van de Ren, R., 2000. Lamb production from diverse genotypes 2. Carcass characteristics. *Anim. Sci.* 70, 147-156.
- Gilmour, A.R., Luff, A.F., Fogarty, N.M. & Banks, R., 1994. Genetic parameters for ultrasound fat depth eye muscle measurements in live Poll Dorset sheep. *Aust. J. Agric. Res.* 45, 1281-1291.
- Gooden, J.M., Beach, A.D. & Purchas, R.W., 1980. Measurements of subcutaneous backfat depth in live lambs with an ultrasonic probe. *N. Z. J. Agric. Res.* 23, 161-165.
- Grundy, S.M. & Denke, M.A., 1990. Dietary influences on serum lipids. *J. Lipid Res.* 31, 1149-1172.
- Hoon, J.H., Herselman, M.J., Van Heerden, M. & Pretorius, A.P., 2000. The effect of bypass protein supplementation on the reproductive performance of Merino sheep grazing mixed Karoo veld. *S. Afr. J. Anim. Sci.* 30 (3), 60-61.
- Jeremiah, L.E., Jones, S.D.M., Tong, A.K.W., Robertson, W.M. & Gibson, L.L., 1997. The influence of lamb chronological age, slaughter weight and gender on yield and cutability. *Sheep Goat Res.* 13 (1), 39-46.

- Kirton, A.H., Clarke, J.N. & Hickey, S.M., 1982. A comparison of the composition and carcass quality of Kelly and Russian castrate, ram, wether and ewe lambs. *Proc. N. Z. Soc. Anim. Prod.* 42, 17-118.
- Lawrie, R.A., 1998. *Lawrie's Meat Science*. Sixth Edition. Woodhead Publishing Limited, Cambridge, England.
- Mahgoub, O. & Lodge, G.A., 1998. A comparative study on growth, body composition and carcass tissue distribution in Omani sheep and goats. *J. Agric. Sci. Cam.* 131, 329-339.
- McGeehin, B., Sheridan, J.J. & Butler, F., 2001. Factors affecting the pH decline in lamb after slaughter. *Meat Sci.* 58, 79-84.
- Metherell, J.A., 1984. Management and breeding policies for the use of the Booroola F gene for increased flock prolificacy. *Proc. N.Z. Soc. Anim. Prod.* 44, 37-40.
- Meyer, H.H., Haribaskar, S., Adbulkhaliq, A.M. & Thompson, J.M., 1998. Callipyge gene effects on lamb growth, carcass traits, muscle weights and meat characteristics. 6th World Congress on Genetics Applied to Livestock Prod (Armidale, Australia). 25, 161-164.
- McEwan, J.C., Clarke, J.N., Hickey, S.M. & Knowler, K.J., 1993. Heritability of ultrasonic fat and muscle depths in Romney sheep. *Proc. N. Z. Soc. Anim. Prod.* 53, 347-350.
- Neser, F.W.C., Erasmus, G.J. & Van Wyk, J.B., 2000. Genetic studies on the South African Mutton Merino: growth traits. *S. Afr. J. Anim. Sci.* 30 (3), 172-177.
- Notter, D.R., 1987. The crossbred sire: Theory. *J. Anim. Sci.* 65, 99-109.
- Olivier, J.J., 1999. The South African Merino performance testing scheme. *In: Premium Quality Wool Symposium. Proc. Advmt. Anim. Breed. Genet.* 13, 119-124.
- Ponzoni, R.W., Fleet, M.R., Walkley, J.R.W. & Walker, S.K., 1985. A note on the effect of the F gene on wool production and live weight of Booroola X South Australia Merino lambs. *Anim. Prod.* 40, 367-369.
- Purchas, R.W., 1978. Some effects of nutrition and castration on meat production from male Suffolk cross (Border Leicester-Romney cross) lambs. 1. Growth and carcass quality. *N. Z. J. Agric. Res.* 21, 37-376.
- USDA, 2001. Lamb, domestic, composition of trimmed retail cuts, separable fat, trimmed to ¼ fat, choice, raw. <http://www.nal.USDA.gov/fnic/foodcomp/index.html>.
- Van der Merwe, C.A., 1976. Genetiese en nie-genetiese faktore wat die produksie en reproduksie eienskappe van die Elsenburg Dormer Skaapkudde beïnvloed. Ph.D. Agric. University of Stellenbosch.

- Visscher, A.H., Dijkstra, M., Lord, E.A., Süß, R., Rösler, H-J., Heylen, K. & Veerkamp, R.F., 2000. Maternal and lamb carrier effects of the Booroola gene on food intake, growth and carcass quality of male lambs. *Anim. Sci.* 71, 209-217.
- Wan, J.M.F., Haw, M.P. & Blackburn, G.L., 1989. Nutrition, immune function and inflammation: an overview. *Proc. Nutr. Soc.* 48, 315-335.
- Webb, E.C., Bosman, M.J. & Casey, N.H., 1994. Dietary influence on subcutaneous fatty acid profiles and sensory characteristics in Dorper and SA Mutton Merino wethers. *S. A. J. Food. Sci. Nutr.* 6, 45-50.
- Wylie, A.R.G., Chestnutt, D.M.B. & Kilpatrick, D.J., 1997. Growth and carcass characteristics of heavy slaughter weight lambs: effects of sire breed and sex of lamb relationship to serum metabolites and IGF-1. *Anim. Sci.* 64, 309-318.
- Wolf, B.T., Smith, C., King, J.W.B. & Nicholson, D., 1981. Genetic parameters of growth and carcass composition in crossbred lambs. *Anim. Prod.* 32, 1-7.

Chapter 2

SLAUGHTER TRAITS IN MERINO LINES DIVERGENTLY SELECTED FOR MULTIPLE REARING ABILITY

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ABSTRACT

Data of 114 19-month-old Merino sheep descended from two lines that were divergently selected for maternal multiple rearing ability (H and L lines, respectively) were used. In study A only ram progeny of the same age were slaughtered, whilst selection line, birth type and sex were included in study B. Study A: Mean (\pm SE) slaughter weight of H line rams was 12% heavier than that of L line contemporaries. Corresponding differences of 13% were found for carcass weight. Carcass component weights, body measurements, retail cut weights and eye-muscle areas were generally higher in the H line than in the L line, barring a few exceptions. Adjustment for the higher live weight resulted in most of the line differences being eliminated. Study B: Mean (\pm SE) slaughter weight of H line animals was 7% heavier than that of L line contemporaries. A corresponding difference of 11% was found for carcass weight between the two lines (pooled sexes). There were no differences in cooking and drip loss between the H and L lines. No difference in the colour of the meat was observed between the two lines, except for the a* reading where the difference between the two lines was significant. pH₄₅ differed between the H and L lines. Adjustment for the higher live weight resulted in most of the line differences being eliminated. Meat from the *m. longissimus dorsi* of L line animals was healthier according to their PUFA/SFA ratio than that of the H line animals.

Keywords: Carcass, carcass composition, meat yield, Merino, multiple births, physical meat quality

INTRODUCTION

Reproduction of sheep plays a major role in the economic viability of the industry in South Africa (Olivier, 1999). Breeding is one of the avenues to be explored in a quest for an improved reproduction rate. Reproduction and survival rates are two important factors determining the efficiency of lamb production (Olivier *et al.*, 1998). Prolificacy of the dam and the growth rate and

slaughter quality of her offspring determine the efficiency of a lamb-meat production system (Visscher *et al.*, 2000). The effect of the presence of the Booroola gene on reproduction has been studied widely (Metherell, 1984; Ponzoni *et al.*, 1985; Bradford & Quirke, 1986; Visscher *et al.*, 2000). Visscher *et al.* (2000) found that Merino crosses which combine the Booroola gene had relatively bigger and fatter carcasses compared to their contemporaries without the gene. The latter physical meat quality characteristic is not acceptable to the consumer. The effects of selection for an increased reproduction rate on carcass weight, mutton production, carcass characteristics and meat quality in Merino sheep have not yet been investigated.

In the sheep industry production costs are high and profit margins are small at all stages of production. If economic production and consumption are striven for, attention has to be paid to meat quality (Sañudo *et al.*, 1998). Jeremiah *et al.* (1997) also expressed the need for definite research to provide guidelines to optimise the balance between carcass weight, quantitative yield of retail cuts and meat quality. Meyer *et al.* (1998) studied the effects of the callipyge gene on lamb growth, carcass traits, muscle weight and meat characteristics. They found that lambs with the callipyge gene had higher growth rates and muscle weights, but that the shearing value of the meat was very high and might not be acceptable to consumers.

This paper examines the effect of divergent selection for an increased reproduction rate on carcass weight, mutton production, meat quality and carcass characteristics of similar-aged Merino sheep.

MATERIALS AND METHODS

Data of 114 19-month-old Merino sheep (40 ewes and 74 rams) were used in this study. The study was done in two parts over two years. Only rams (52) were slaughtered over a two-week period in study A. Twenty-two rams and 40 ewes were slaughtered over a three-week period in study B. The sheep were descended from two selection lines, a high (H) line and a low (L) line. Numbers within lines were 89 and 23 individuals respectively. The lines have been divergently selected for maternal multiple rearing ability since 1986. Cloete & Scholtz (1998) have described the selection procedure in detail. In brief, ewe and ram progeny of ewes rearing more than one lamb per joining (i.e. that reared twins at least once) were preferred as replacements in the H line. Descendants of ewes that reared fewer than one lamb per joining (i.e. that were barren or lost all lambs born at least once) were preferred as replacements in the L line (Cloete & Scholtz, 1998). The sheep used in study A were the 4th and that in study B the 5th generation that has been exposed to these selection parameters.

All the sheep in the same study (A or B) were maintained in the same flock from birth until slaughter at 19-months of age. Both lines were subjected to the same level of husbandry (e.g. parasite control, weaning period) during this period. The sheep were sheared approximately 21 days prior to being slaughtered. Live weight was determined 24 hours prior to slaughtering (Hopkins *et al.*, 1996). The sheep were slaughtered at a commercial abattoir using standard South African slaughter techniques and then stunned electrically (4 seconds at 200 Volts) before being exsanguinated. The carcasses were subsequently hung to bleed out and then skinned. One day after slaughter the carcasses were transported from the abattoir to a deboning facility, where they were kept for another 24 hours prior to deboning and sampling.

Study A: Recordings on the carcass included the weight of carcass components, cold carcass weight (after 24 hours in a cooler at 2°C), the weight of the retail cuts and backfat depth. The latter was taken at a site 25 mm off the midline at the 13th rib (Gilmour *et al.*, 1994). Carcass components that were weighed included the head, trotters, skin and measuring the thickness of the skin (measured at the same site as backfat depth). Carcass length was measured on the hanging carcass from the anterior tip of the pubis bone to the front of the first rib. The leg circumference was measured at two points: the first leg circumference (1) was taken at the maximum circumference of a line passing over the distal end of the iliac wings of the pelvis and the most caudal point on the median line between the legs (Stanford *et al.*, 1997), and the second leg circumference (2) was taken at the stifle (Oman *et al.*, 1999). Hind leg length was measured from the inner edge of the proximal end of the tibia to the anterior tip of the pubis (Enright, 1990). The eye-muscle area was also measured at the 13th rib (Gilmour *et al.*, 1994). This was done by tracing the eye-muscle circumference onto wax paper. The silhouette of the eye muscle was then passed through a Li Cor LI3100 (1 mm² resolution) for the determination of surface area. Each silhouette was measured in 5 fold and the mean used in the statistical analysis of the data.

After 48 hours in the cooler the carcasses were partitioned into different retail cuts, which were weighted separately. These cuts consisted of the neck, shoulder, chuck, flatrib, prime rib, loin and hindquarters (Holcombe *et al.*, 1999). The neck was removed at the seventh cervical vertebrae (the point where the neck starts bending), the cut being made at right angles to the spine. Thereafter the hind legs were removed. This consisted of loosening the flanks on the inside of the legs (following the curve of the leg muscle) to an imaginary line perpendicular to the ilium (seen from the inside of the carcass). The leg was then removed by cutting along this line, just missing the ilium (through the last lumbar vertebrae). The rest of the carcass was then halved prior to being separated into trade cuts. The shoulder was removed by sawing along an imaginary line from the

elbow joint to a point below the spinal column, between the fifth and sixth ribs. The carcass was then swiveled so that the spinal column was sawn through at right angles. The flank was removed by sawing from the *obliquus abdominis internus* muscle parallel to the spine. The loin and rib were separated perpendicularly to the spinal column at the junction of the thoracic and lumbar vertebrae. All commercial cuts were weighed on a digital computing scale to the nearest gram (Hoffman, 2000).

Study B: The same slaughtering procedures were used as in study A. Most of the recordings in this study were similar to those in the first. In addition to these measurements the carcass depth and width were also taken on the hanging carcass (Kenney *et al.*, 1995). The pH of the *longissimus dorsi* muscle from the right side of the carcass was also measured between the 11th and 13th rib at three different times, namely 45 minutes, 24 hours and 48 hours after slaughter (McGeehin *et al.*, 2001). After 48 hours the carcasses were cut into the different retail cuts, which were weighed separately (Hoffman, 2000). These cuts were the same as in study A, except for the hind legs, which were cut at the second last lumbar vertebrae and not the last. The hind leg length and circumference were also measured. The backfat depth was taken at a site 25 mm off the midline at the 13th rib. The eye-muscle areas were also determined as in study A.

The loin retail cut of 26 carcasses (6 H line and 6 L line rams; 7 H line and 7 L line ewes) were randomly removed and taken to the laboratory for the measurement of various physical meat-quality attributes. The *longissimus dorsi* muscle was dissected from the 1st to the 6th lumbar vertebrae and used for these analyses (Schönfeldt *et al.*, 1993). Two loin sub-samples (the first taken at the first lumbar vertebrae and the second caudally adjacent to it) were taken for the determination of cooking loss, drip loss, colour (after blooming for 30 minutes) and meat tenderness (Honikel, 1998). The colour was evaluated by using a Color-guide 45°/0° colorimeter (BYK-Gardner, USA) to determine L*, a* and b* values (Commission International de l'Éclairage, 1976), with L* indicating brightness, a* the red-green range and b* the blue-yellow range. Tenderness of the meat (same sample as used for cooking loss) was measured with the Warner-Bratzler shear force test using 1.27 cm diameter samples in triplicate (Honikel, 1998). The measuring speed was 200.0 mm/min.

The remaining part of the *longissimus dorsi* muscle was minced, freeze-dried and analysed for proximate chemical composition. The protein was measured by a FP-428 Nitrogen and Protein Determinator (Leco). Lipid (petroleum ether extraction) was measured according to ALASA (1995). Moisture content was determined by drying a sample (± 1.0 g) at 100°C to a constant weight and ashing overnight at 500°C (ALASA, 1995).

Muscle and fat of the *m. longissimus dorsi* were used for fatty acid analysis. Fatty acid methyl esters (FAME) were prepared according to the method of Morrison & Smith (1964) and analysed on a GLC (Varian Model 3300), equipped with flame ionisation detection and two 30 m fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&W Scientific Folsom, CA). Gas flow rates were: hydrogen, 25 ml/min; air, 250 ml/min; and nitrogen (carrier gas), 5-8 ml/min. Temperature programming was linear at 4°C/min; initial temperature, 160°C; final temperature, 220°C held for 10 min; injector temperature, 240°C; and detector temperature, 250°C. The FAME were identified by comparison of the retention times of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Prior to testing for differences of the various parameters between the two lines and sexes, an analysis of variation was done according to a 2 (lines; H and L) x 2 (birth type; singles and pooled multiples) factorial design in study A and B. Least squares procedures were used to account for the higher multiple birth rate in H line progeny in the estimation of the means (Harvey, 1990). Line did not interact ($P < 0.05$) with birth type in any of the studies and these results are thus not presented. There was also no significant interaction between sex and line in study B. Adjustment for the higher mean live weight of the H line animals and rams was done by analysis of covariance. Only the main effects of line (both studies) and sex (study B) is thus presented. The differences between the various parameters determined for the two lines and between sexes were tested separately by means of the null hypothesis (H_0) with $H_0: \mu = \mu_0$ and the alternative hypothesis (H_μ) being $H_\mu: \mu \neq \mu_0$. This was done by means of contrast analysis and estimated least square means (\pm SE) as reported in the tables. Differences between the variables were accepted as being significant if the possibility of rejection of H_0 was equal to or less than 5% ($P \leq 0.05$) and highly significant if equal to or less than 1% ($P \leq 0.01$) between the two lines or sexes.

RESULTS

Study A: The mean slaughter weight of the H line rams was 12% heavier ($P < 0.01$) than that of L line contemporaries (Table 1). A corresponding difference ($P < 0.01$) of 13% was found for the mean carcass weight. Mean carcass component weights, retail cut weights and eye-muscle area were generally higher ($P < 0.05$) in the H line than in the L line, barring a few exceptions. Among these were a suggestion of a heavier mean skin weight ($P = 0.20$) and greater skin thickness ($P = 0.07$) in L line animals compared to H line contemporaries. Mean carcass length and leg circumference were generally higher ($P < 0.01$) in the H line than in the L line (Table 1).

Adjustment for the higher mean live weight of H line rams by analysis of covariance resulted in most of the line differences being eliminated ($P>0.05$). The adjusted means of the parameters that still differed ($P<0.05$) between the two selection lines are shown in Table 2. The difference in the adjusted mean weight of the retail loin cut remained in heavier in the H line after being adjusted for higher slaughter weight ($P<0.05$). The mean skin weight ($P<0.01$) and skin thickness ($P<0.05$) were heavier and thicker in L line rams than in H line contemporaries after adjustment for live weight. Rams in the L line also had heavier ($P<0.05$) trotters than the H line contemporaries after adjustment for slaughter weight.

Table 1: The means (\pm SE) of carcass traits of 19-month-old Merino rams selected for (H line $n=42$) and against (L line $n=10$) maternal multiple rearing ability, before adjustment for higher live weight (study A).

Trait	H line	L line	Significance
<u>Carcass characteristics</u>			
Slaughter weight (kg)	47.8 \pm 0.09	42.6 \pm 1.6	P=0.007
Carcass weight (kg)	17.6 \pm 0.36	15.5 \pm 0.63	P=0.005
Dressing %	36.7 \pm 4.29	36.37 \pm 2.91	P=0.150
Skin weight (kg)	3.42 \pm 0.09	3.65 \pm 0.15	P=0.200
Skin thickness (mm)	1.96 \pm 0.05	2.15 \pm 0.09	P=0.070
Trotters (kg)	0.97 \pm 0.02	0.99 \pm 0.04	P=0.970
Head (kg)	3.94 \pm 0.07	3.50 \pm 0.13	P=0.040
Carcass length (cm)	78.04 \pm 0.46	75.78 \pm 0.80	P<0.001
Leg length (cm)	34.44 \pm 0.41	34.03 \pm 0.71	P=0.620
Leg circumference (1) (cm)	38.86 \pm 0.35	36.90 \pm 0.61	P=0.007
Leg circumference (2) (cm)	27.54 \pm 0.33	26.15 \pm 0.058	P=0.044
Eye-muscle area 13 th rib (cm ²)	10.4 \pm 0.26	8.95 \pm 0.45	P=0.049
Fat depth 13 th rib (mm)	0.50 \pm 0.11	0.29 \pm 0.19	P=0.450
<u>Retail cuts</u>			
Neck (kg)	0.97 \pm 0.03	0.84 \pm 0.04	P=0.015
Shoulder (kg)	2.97 \pm 0.15	2.68 \pm 0.14	P=0.032
Chuck (kg)	3.05 \pm 0.07	2.62 \pm 0.12	P=0.043
Flat rib (kg)	1.92 \pm 0.05	1.68 \pm 0.09	P=0.026
Prime rib (kg)	1.29 \pm 0.04	1.19 \pm 0.07	P=0.086
Loin (kg)	1.70 \pm 0.05	1.30 \pm 0.08	P=0.015
Hindquarters (kg)	5.58 \pm 0.11	5.09 \pm 0.20	P=0.036

Table 2: Mean adjusted weights of carcass components that differed statistically between the H and L lines after adjustment for live weight at slaughter (study A).

Weight	H line	L line	Significance
<u>Carcass characteristics</u>			
Skin weight (kg)	3.34 ± 0.07	3.93 ± 0.15	P<0.001
Skin thickness (kg)	1.97 ± 0.18	2.28 ± 0.11	P=0.016
Trotters (kg)	0.96 ± 0.02	1.05 ± 0.03	P=0.018
<u>Retail cuts</u>			
Loin (kg)	1.64 ± 0.04	1.37 ± 0.08	P=0.003

Study B: As there were no significant sex x line interactions the data were analysed to test for the main effects of line and sex. The means (\pm SE) of the various carcass parameters measured are shown in Table 3. The mean slaughter weight before adjustment for higher live weight of H line animals was only 7% heavier ($P=0.05$) than that of the L line contemporaries in this study. Mean slaughter weight of the rams was 15% heavier ($P<0.01$) than that of ewes. A corresponding difference ($P<0.05$) of 11% was found for carcass weight between the two lines. However, there was only a tendency for rams to have heavier carcasses than ewes ($P=0.09$).

In study B most of the differences were similar between the two lines as found in study A, except that there was no difference in the means of the trotters, shoulder and loin retail cuts between the two lines (Table 3). The mean carcass length ($P<0.01$) and leg circumference ($P<0.01$) were generally higher in the H line than in the L line (Table 3). The mean leg length of the H line was longer than that of the L line animals (Table 3). The neck and shoulder retail cut weights were generally higher for rams than for ewes. For the chuck, flatrib and prime rib retail cuts no differences were found. The loin retail cut and eye-muscle area of the ewes were higher ($P<0.01$) than those of the rams (Table 3). The mean carcass length, depth and width of rams were generally higher ($P<0.01$) than in ewes, but there were no differences in leg circumferences (Table 3).

Table 3. The means (\pm SE) of various carcass traits of 19-month-old Merino sheep selected for (H line) and against (L line) maternal multiple rearing ability and differences between sexes, before adjustment for higher live weight (study B).

Trait	Line			Sex		
	H line	L line	Significance	Ram	Ewe	Significance
Number	49	13		22	40	
<u>Carcass characteristics</u>						
Slaughter weight (kg)	44.02 \pm 0.69	41.21 \pm 1.26	P=0.050	45.55 \pm 1.09	39.69 \pm 0.95	P<0.001
Carcass weight (kg)	16.03 \pm 0.03	14.44 \pm 0.55	P=0.010	15.76 \pm 0.47	14.7 \pm 0.41	P=0.090
Dressing %	36.46 \pm 0.33	35.10 \pm 0.60	P=0.050	34.56 \pm 0.51	37.01 \pm 0.44	P<0.001
Skin weight (kg)	4.77 \pm 0.10	5.16 \pm 0.19	P=0.070	5.45 \pm 0.16	4.48 \pm 0.14	P<0.001
Trotters (kg)	0.86 \pm 0.01	0.84 \pm 0.02	P=0.470	0.93 \pm 0.02	0.78 \pm 0.02	P<0.001
Head (kg)	3.02 \pm 0.05	2.86 \pm 0.09	P=0.110	3.62 \pm 0.07	2.26 \pm 0.06	P<0.001
Carcass length (cm)	72.92 \pm 0.38	70.69 \pm 0.69	P=0.007	73.82 \pm 0.59	69.79 \pm 0.52	P<0.001
Carcass depth (cm)	29.30 \pm 0.22	27.13 \pm 0.40	P<0.001	29.19 \pm 0.34	27.23 \pm 0.30	P<0.001
Carcass width (cm)	22.51 \pm 0.20	21.70 \pm 0.37	P=0.062	22.71 \pm 0.32	21.50 \pm 0.30	P=0.006
Leg length (cm)	33.78 \pm 0.37	32.12 \pm 0.67	P=0.034	34.10 \pm 0.57	31.80 \pm 0.50	P=0.004
Leg circumference(1) (cm)	37.19 \pm 0.28	35.39 \pm 0.50	P=0.004	36.58 \pm 0.43	35.93 \pm 0.38	P=0.250
Leg circumference(2) (cm)	24.23 \pm 0.18	23.04 \pm 0.036	P=0.006	23.88 \pm 0.31	23.39 \pm 0.27	P=0.230
Eye-muscle area (cm ²)	9.60 \pm 0.23	8.30 \pm 0.42	P=0.008	8.32 \pm 0.34	9.59 \pm 0.31	P=0.009
Fat depth (mm)	1.40 \pm 0.16	1.49 \pm 0.29	P=0.780	1.04 \pm 0.24	1.86 \pm 0.21	P=0.018
<u>Retail cuts</u>						
Neck (kg)	0.85 \pm 0.02	0.74 \pm 0.03	P=0.006	0.97 \pm 0.03	0.62 \pm 0.03	P=0.001
Shoulder (kg)	0.80 \pm 0.04	0.77 \pm 0.03	P=0.370	0.82 \pm 0.02	0.73 \pm 0.02	P=0.016
Chuck (kg)	4.75 \pm 0.09	4.34 \pm 0.16	P=0.040	4.65 \pm 0.14	4.45 \pm 0.12	P=0.290
Flatrib (kg)	1.49 \pm 0.05	1.29 \pm 0.08	P=0.040	1.39 \pm 0.07	1.39 \pm 0.06	P=0.940
Prime rib (kg)	1.19 \pm 0.03	1.05 \pm 0.05	P=0.030	1.15 \pm 0.05	1.09 \pm 0.04	P=0.300
Loin (kg)	1.78 \pm 0.07	1.73 \pm 0.13	P=0.750	1.56 \pm 0.11	1.95 \pm 0.09	P=0.009
Hindquarters (kg)	4.78 \pm 0.08	4.21 \pm 0.14	P<0.001	4.78 \pm 0.12	4.12 \pm 0.11	P<0.001

Adjustment for the higher mean live weight of H line animals by analysis of covariance resulted in most of the line differences being eliminated ($P>0.05$). The adjusted means for the parameters that still tended to differ ($P<0.10$) between the two selection lines are shown in Table 4.

Table 4. Mean adjusted weights of carcass components that still differed statistically between the H and L lines and sexes after adjustment for live weight at slaughter (study B).

Trait	Line			Sex		
	H line	L line	Significance	Ram	Ewe	Significance
Number	49	13		22	40	
<u>Carcass characteristics</u>						
Carcass weight (kg)	15.46 ± 0.14	14.96 ± 0.25	P=0.096	14.61 ± 0.23	15.80 ± 0.20	P<0.001
Dressing %	36.39 ± 0.34	35.17 ± 0.61	P=0.089	34.41 ± 0.55	37.15 ± 0.48	P<0.001
Skin weight (kg)	4.73 ± 0.09	5.35 ± 0.16	P=0.008	5.28 ± 0.14	4.80 ± 0.15	P=0.030
Trotters (kg)				9.16 ± 0.02	7.80 ± 0.02	P<0.001
Head (kg)				3.38 ± 0.04	2.35 ± 0.05	P<0.001
Carcass length (cm)	72.53 ± 0.35	71.05 ± 0.61	P=0.040	73.03 ± 0.56	70.55 ± 0.49	P=0.002
Carcass depth (cm)	29.02 ± 0.18	27.38 ± 0.32	P=0.001	28.63 ± 0.30	27.77 ± 0.26	P=0.040
Leg circumference (1) (cm)	36.69 ± 1.99	35.77 ± 0.35	P=0.030	35.72 ± 0.32	36.75 ± 0.28	P=0.027
Leg circumference (2) (cm)	23.94 ± 0.15	23.31 ± 0.27	P=0.046	23.30 ± 0.24	23.95 ± 0.21	P=0.060
Eye-muscle area (cm ²)	9.35 ± 0.20	8.53 ± 0.36	P=0.060	7.80 ± 0.33	10.08 ± 0.29	P<0.003
<u>Retail cuts</u>						
Neck (kg)				0.87 ± 0.02	0.63 ± 0.02	P<0.001
Chuck (kg)				4.32 ± 0.10	4.47 ± 0.11	P=0.010
Flatrib (kg)				1.24 ± 0.05	1.54 ± 0.06	P=0.003
Prime rib (kg)				1.04 ± 0.03	1.20 ± 0.04	P=0.004
Loin (kg)				1.42 ± 0.10	2.18 ± 0.11	P<0.001
Hindquarters (kg)	4.61 ± 0.07	4.27 ± 0.12	P=0.009	4.58 ± 0.10	4.29 ± 0.11	P=0.074

The difference in the mean adjusted weight of the retail hindquarters cut remained in significantly higher for the H line after being adjusted for higher slaughter weight ($P<0.01$). The mean carcass length, depth ($P<0.01$) and leg circumferences also remained higher ($P<0.05$) in the H line after adjustment for slaughter weight. The adjusted mean skin weight ($P<0.01$) was accordingly heavier in L line animals than in H line contemporaries.

After adjustment for the higher mean live weight of the rams by analysis of covariance, all the differences in carcass component weights remained significantly in higher in the rams, the exception being carcass weight, dressing % ($P<0.001$) and leg circumference (1) that were higher ($P<0.05$) in the ewes than in the rams. In all the adjusted mean retail cuts, weights were generally

heavier ($P < 0.05$) in the ewes, except for the neck and hindquarters weights that were heavier ($P < 0.05$) in the rams (Table 4).

The physical meat-quality attributes of the sheep from study B are shown in Table 5. There was no differences in mean cooking and drip loss between the H and L lines, but the mean cooking loss of the rams was higher ($P < 0.05$) than that of the ewes, whilst the drip loss of the ewes was higher ($P < 0.05$) than that of the rams. The meat of the rams was more tender ($P < 0.01$) than that of the ewes. Animals in the L line tended ($P = 0.16$) to have more tender meat than contemporaries in the H line. There was no difference in the colour of the meat between the two sexes. The only line difference ($P < 0.05$) that was found was for the a^* reading (Table 5), suggesting that meat from the H line was a saturated red as apposed to meat from the L line. The pH of H line animals was higher ($P < 0.05$) than that of L line animals when assessed 45 minutes post slaughter for all the sheep in study B (Table 5). An opposite tendency ($P = 0.07$) was found 24 hours post slaughter, while no difference was found 48 hours post slaughter. Rams had higher ($P < 0.05$) pH measurements than ewes at 48 hours post slaughter (Table 5).

Table 5. Meat-quality parameters of sheep divergently selected for and against multiple rearing ability and differences between sexes (study B).

Parameter	Line		Significance	Sex		Significance
	H line (n=13)	L line (n=13)		Ram (n=12)	Ewe (n=14)	
pH ₄₅	6.72 ± 0.05	6.45 ± 0.10	P=0.050	6.70 ± 0.08	6.49 ± 0.07	P=0.080
pH ₂₄	5.79 ± 0.03	5.90 ± 0.55	P=0.068	5.89 ± 0.05	5.81 ± 0.04	P=0.260
pH ₄₈	5.72 ± 0.02	5.70 ± 0.45	P=0.350	5.84 ± 0.04	5.58 ± 0.03	P=0.001
Cooking loss %	27.98 ± 1.26	27.27 ± 1.25	P=0.820	30.18 ± 1.3	25.39 ± 1.20	P=0.015
Drip loss %	1.31 ± 0.10	1.37 ± 0.10	P=0.700	1.15 ± 0.01	1.52 ± 0.10	P=0.018
Tenderness (N)	127.9 ± 7.24	113.0 ± 7.24	P=0.160	99.46 ± 7.51	141.4 ± 6.96	P<0.001
Colour L*	33.07 ± 0.74	32.73 ± 0.74	P=0.740	32.56 ± 0.77	33.23 ± 0.71	P=0.520
a^*	13.26 ± 0.24	12.43 ± 0.24	P=0.021	12.63 ± 0.25	13.06 ± 0.23	P=0.220
b^*	8.26 ± 0.28	7.97 ± 0.28	P=0.470	8.26 ± 0.29	7.96 ± 0.27	P=0.460

There was no difference between the mean proximate chemical composition of the *longissimus dorsi* muscle (sampled from the 1st to the 6th lumbar vertebrae) of the H and L lines (Table 6). The moisture content of the meat from the rams (pooled lines) was higher ($P < 0.01$) than that of the ewes, and the lipid content of the meat from the ewes was higher ($P < 0.01$) than that from the rams (Table 6).

Table 6. Mean (\pm SE) proximate chemical composition of the 11/13th-rib cut (*m. longissimus dorsi*) of sheep divergently selected for and against multiple rearing ability and differences between sexes (study B).

Trait	Line			Sex		
	H line	L line	Significance	Ram	Ewe	Significance
Number	13	13		12	14	
Moisture	65.07 \pm 1.73	64.86 \pm 1.73	P=0.931	69.00 \pm 1.80	60.93 \pm 1.66	P=0.003
Protein	19.67 \pm 1.10	19.39 \pm 1.10	P=0.857	19.42 \pm 1.10	19.64 \pm 1.10	P=0.881
Lipid	15.60 \pm 2.0	16.84 \pm 2.00	P=0.662	11.58 \pm 2.10	20.86 \pm 1.92	P=0.003
Ash	0.99 \pm 0.05	0.95 \pm 0.05	P=0.558	1.00 \pm 0.05	0.94 \pm 0.04	P=0.326

In general there were no statistically significant differences in the fatty acid composition between the H and L line animals. The two most prominent saturated fatty acids (SFA) were palmitic (C16:0) and stearic acid (C18:0). Oleic acid (C18:1n9) was the most prominent mono-unsaturated fatty acid whilst linoleic (C18:2n6) and α -linolenic acid (C18:3n3) were the most prominent polyunsaturated fatty acids (PUFA). Animals in the L line had a higher ($P<0.05$) PUFA:SFA ratio than H line contemporaries (Table 7).

Table 7. The means (\pm SE) of various fatty acids compositions (expressed as proportion of total fatty acid/100) of muscle and fat from the *m. longissimus dorsi*, of 19-month-old Merino rams selected for (H line n=16) and against (L line n=16) maternal multiple rearing ability (study A and B).

Trait	H line	L line	Significance
<u>Fatty acids</u>			
C14:0	2.27 \pm 0.18	2.28 \pm 0.18	P=0.981
C16:0	23.50 \pm 0.79	23.53 \pm 0.77	P=0.976
C18:0	29.83 \pm 1.05	27.53 \pm 1.03	P=0.130
C20:0	0.51 \pm 0.04	0.45 \pm 0.03	P=0.252
C22:0	0.14 \pm 0.02	0.13 \pm 0.02	P=0.659
C24:0	0.16 \pm 0.06	0.10 \pm 0.06	P=0.506
SFA ¹⁾	56.50 \pm 1.04	54.18 \pm 1.02	P=0.123
C16:1n7	0.11 \pm 0.01	0.11 \pm 0.01	P=0.559
C18:1n9	35.28 \pm 1.23	36.53 \pm 1.20	P=0.471
C20:1n9	0.19 \pm 0.02	0.16 \pm 0.02	P=0.271
C24:1n9	0.08 \pm 0.02	0.06 \pm 0.02	P=0.243
MUFA ²⁾	36.61 \pm 1.24	37.87 \pm 1.21	P=0.475
C18:2n6	3.73 \pm 0.20	4.21 \pm 0.20	P=0.101
C18:3n6	0.048 \pm 0.001	0.045 \pm 0.008	P=0.760
C18:3n3	1.27 \pm 0.12	1.57 \pm 0.13	P=0.098
C20:2n6	0.06 \pm 0.01	0.054 \pm 0.01	P=0.588
C20:3n6	0.086 \pm 0.02	0.081 \pm 0.02	P=0.890
C20:4n6	0.49 \pm 0.09	0.63 \pm 0.08	P=0.266
C20:3n3	0.018 \pm 0.002	0.029 \pm 0.002	P=0.635
C20:5n3	0.25 \pm 0.05	0.36 \pm 0.05	P=0.157
C22:2n6	0.39 \pm 0.11	0.37 \pm 0.11	P=0.910
C22:4n6	0.08 \pm 0.03	0.06 \pm 0.03	P=0.678
C22:5n3	0.33 \pm 0.06	0.42 \pm 0.06	P=0.279
C22:6n3	0.08 \pm 0.01	0.10 \pm 0.01	P=0.236
PUFA ³⁾	6.78 \pm 0.48	7.87 \pm 0.47	P=0.118
PUFA/SFA ⁴⁾	0.120 \pm 0.009	0.145 \pm 0.008	P=0.041

¹⁾ Saturated fatty acids

²⁾ Mono-unsaturated fatty acids

³⁾ Polyunsaturated fatty acids

⁴⁾ Polyunsaturated fatty acids: Saturated fatty acids

DISCUSSION

Mean birth and weaning weights differed between the two selection lines, with the birth weight of the H line animals the highest (Cloete & Scholtz, 1998). The heavier slaughter weights of the H line in both years can either be associated with the higher birth weights of the H line animals or they could be attributed to differences in growth rate as reflected by weaning weight (Kirton *et al.*, 1995). All the carcass component weights, retail cut weights and eye-muscle areas were generally higher in the H line than in the L line. These differences were associated with the higher slaughter weight of the H line animals (Table 1).

The higher dressing % of the H line sheep and the ewes could be related to the heavier skins of the L line animals and the rams (Tables 1 and 3). The difference in dressing % between the rams and ewes could also be due to the fact that the heads of the rams were significantly heavier ($P < 0.01$) (because of the much bigger horns) than those of the ewes (Table 4). In study B the larger leg circumference of the H line animals could be associated with the higher hindquarter weight of the H line animals.

However, after adjustment for the heavier live weight of the H line rams, the skin weight and skin thickness of L line rams became significantly heavier and thicker (study A, Table 2). In study B a similar difference in skin weight was found after adjustment for the heavier live weights of the H line sheep. The skins of the rams were also heavier than those of the ewes (study B, Table 4). The heavier skin weight of the L line was probably related to skin thickness. Williams & Thornberry (1992) found that Merinos that were descended from a high wool-producing flock had thicker skins in comparison with a low wool-producing flock. In this flock, there was no conclusive difference in genetic trends for two-tooth clean fleece weight between the H and L lines (Cloete & Olivier, 1998). Williams & Thornberry (1992) found a positive ($P < 0.05$), although small, relationship between skin thickness and wrinkling. Cloete & Olivier (1998) reported that the genetic change in fold score in the L line flock was positive (i.e. the animals became more developed), while H line animals became plainer. This could explain why L line animals had heavier and thicker skins than the H line when adjusted for slaughter weight.

The larger ($P < 0.05$) eye-muscle areas of the H line animals in both studies (Table 1 and 3) and after adjustment for higher live weight (Table 2 and 4) appear to be an indication of the muscle content in the whole carcass (Hopkins *et al.*, 1992). Eye-muscle area was also found to be a significant predictor of muscle in the leg (Hopkins *et al.*, 1992). In study B the loin retail cut did not differ between lines, but the H line had heavier ($P < 0.01$) hindquarter weights (the differences

between the results in the two parts of the experiment could be due to the difference in the partitioning of the retail cuts by different blockmen). The ewes had larger ($P<0.05$) eye-muscle areas than the rams after adjustment for live weight. Fahmy *et al.* (1999) also found that ewes had heavier loin retail cuts and bigger eye-muscle areas than rams. Jeremiah *et al.* (1997) reported similar results as in study B: that rams had heavier neck retail cuts than ewes. This phenomenon of heavier forequarters in rams is typical of sexual dimorphism, and is expected when sheep are slaughtered after sexual maturity.

The higher a^* value of the H line sheep indicated that the meat of the H line was more red than that of the L line (Table 5). This could also be related to the fact that the pH_{45} (Table 5) of the H line animals was higher ($P<0.05$) than that of the L line contemporaries. Priolo *et al.* (2000) and Sañudo *et al.* (1998) found that muscle with a higher pH_{45} tended more towards the saturated red end of the colour scale. The higher pH_{45} value of H line animals suggested that they might have experienced lower stress levels immediately prior to slaughter. The post-mortem pH will be determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis. This will be curtailed if glycogen is depleted by fatigue or fear in the animal before slaughter resulting in a lower initial pH (Lawrie, 1998). This contention cannot be validated, since no measures of stress were recorded, but the two lines were slaughtered at random. Tenderness of meat is affected by ultimate pH (Priolo *et al.*, 2000). Neither tenderness nor pH_{48} differed between the two lines (Table 5), although there was a tendency ($P<0.16$) for H line animals to produce tougher meat than L line contemporaries. Post-mortem muscle temperature has been cited as an important factor in the development of meat tenderness, a higher post-mortem temperature leading to more tender meat (Bruce & Ball, 1990). The differences in tenderness between the ewes and rams (Table 5) could possibly be associated with the significantly ($P<0.01$) higher meat temperature of the rams (7.98°C vs. 6.45°C) than that of the ewes at 48 hours after slaughter. These differences in temperature could be associated with differences in environmental temperature of the days after slaughter (the day after slaughter the carcasses were transported from the abattoir to a deboning facility). The sheep (rams and ewes) were not slaughtered on the same dates. Higher ultimate pH levels result in less “weep” or drip loss (Lawrie, 1998). This could account for the fact that the drip loss was higher in the ewes than the rams, since the ultimate pH of the rams was significantly higher ($P<0.01$). Juiciness of meat is directly related to the intramuscular lipids and moisture content of meat. In combination with water the melted lipids constitute a “broth” that is retained in meat (Schönfeldt *et al.*, 1993). Losses from good-quality meat tend to be less overall than from poor-quality meat. Although the former loses more fat (which is expected in view of a higher fat content), it loses less

moisture, possibly because the structural changes caused by the presence of the fat enhances water-holding capacity; this could be why the cooking loss of the meat from rams was higher than in meat from the ewes (Lawrie, 1998).

Teixeira *et al.* (1996) stated that ewes were fatter than rams of the same age. Similar results were noted in this study, as the proximate chemical analysis of *m. longissimus* showed that the ewes had more intramuscular fat than rams (Table 6). Ram carcasses contained a higher percentage of moisture in the *longissimus* muscle than ewe carcasses, which agrees with the results of Kemp *et al.* (1976). The higher PUFA:SFA ratio of the L line animals meat is an indication that their meat may be healthier (Sañudo *et al.*, 1998) than that of H line animals. It is generally accepted that in humans plasma cholesterol concentration is influenced by the fatty acid composition of dietary fat. High dietary levels of long-chain SFA increase plasma cholesterol levels, while an opposite trend is expected with higher PUFA levels (Grundy & Denke, 1990).

CONCLUSION

The higher weights of the loin (study A) and hindquarter (study B) retail cuts of the H line animals are important observations, since the highest-priced meat cuts are found in these regions. Differences in that higher in the L line were in comparatively lower-priced carcass components, e.g. the skin (in both studies) and trotters (study A). Compared to the Callipyge and Booroola genes which increase growth rates and lambing percentage, but have negative influences on fat content (Booroola) and toughness of the meat (Callipyge), selection for reproduction in Merino sheep seems to have result in no changes in these parameters, but there was a tendency of higher shear force in the H line. Further studies are required to monitor whether selection for reproductive efficiency has any influences on the organoleptic quality of the mutton.

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REFERENCES

- ALASA, 1995. Association of Official Analytical Chemists International, Official methods of analysis of AOAC International, 16th edition, Method 4.5.01 (920.39), AOAC International, Maryland, USA.
- Bradford, G.E. & Quirke, J.F., 1986. Ovulation rate and litter size of Barbados, Targhee and crossbred ewes. *J. Anim. Sci.* 62, 905-909.
- Bruce, H.L. & Ball, R.O., 1990. Postmortem interaction of muscle temperature, pH and extension on beef quality. *J. Anim. Sci.* 68, 4167-4175.
- Cloete, S.W.P. & Olivier, J.J., 1998. Direct and correlated responses to divergent selection for multiple rearing ability in South African Merinos. *Proc. S. Afr. Soc. Anim. Sci.* 36, 65-68.
- Cloete, S.W.P. & Scholtz, A.J., 1998. Lamb survival in relation to lambing and neonatal behaviour in medium wool Merino lines divergently selected for multiple rearing ability. *Aust. J. Exp. Agric.* 38, 801-811.
- Commission International De L' Eclairage, 2nd, 1976. Commission Internationale De L'Eclairage, 18th session, London, England. September 1975. CIE publication no. 36.
- Enright, W.J., Quirke, J.F., Gluckman, P.D., Breier, B.H., Kennedy, L.G., Hart, I.C., Roche, J.F., Coert, A. & Allen, P., 1990. Effects of long-term administration of pituitary-derived bovine growth hormone and estradiol on growth in steer. *J. Anim. Sci.* 68, 2345-2350.
- Fahmy, M.H., Garipey, C. & Fortin, J., 1999. Carcass quality of crossbred lambs expressing the callipyge phenotype born to Romanov purebred and crossbred ewes. *Anim. Sci.* 69, 525-533.
- Gilmour, A.R., Luff, A.F., Fogarty, N.M. & Banks, R., 1994. Genetic parameters for ultrasonic fat depth and eye muscle measurements in live Poll Dorset sheep. *Aust. J. Agric. Res.* 45, 1281-1291.
- Grundy, S.M. & Denke, M.A., 1990. Dietary influences on serum lipids. *J. Lipid Res.* 31, 1149-1172.
- Harvey, W.R., 1990. User's Guide for LSMLMW and MIXMDL. PC-2 version (Mimeograph: Columbus, Ohio, USA).
- Hoffman, L.C., 2000. The yield and carcass chemical composition of impala (*Aepyceros melampus*), a southern African antelope species. *J. Sci. Food Agric.* 80, 752-756.
- Holcombe, D.W., Dils, C.L., Butler, R.F., Ringkob, T.P., Ackerman, C.J. & Judkins, M.B., 1999. Effects of cyclic feeding on performance, carcass characteristics and retail value in lambs. *Sheep Goat Res. J.* 15 (1), 5-14.

- Honikel, K.O., 1998. Reference methods for the assessment of physical characteristics of meat. *Meat Sci.* 49, 447-457.
- Hopkins, D.L., Gilbert, K.D., Pirlot, K.L. & Roberts, A.H.K., 1992. Elliottdale and crossbred lambs: growth rate, wool production, fat depth, saleable meat yield, carcass composition and muscle content of selected cuts. *Aust. J. Exp. Agric.* 32, 429-434.
- Hopkins, D.L., Hall, D.G. & Luff, A.F., 1996. Lamb carcass characteristics 3. Describing changes in carcasses of growing lambs using real-time ultrasound and the use of these measurements for estimating the yield of saleable meat. *Aust. J. Exp. Agric.* 36, 37-43.
- Jeremiah, L.E., Jones, S.D.M., Tong, A.K.W., Robertson, W.M. & Gibson, L.L., 1997. The influence of lamb chronological age, slaughter weight and gender on yield and cutability. *Sheep Goat Res. J.* 13 (1), 39-46.
- Kemp, J.D., Johnson, A.E., Stewart, D.F., Ely, D.G. & Fox, J.D., 1976. Effect of dietary protein, slaughter weight and sex on carcass composition, organoleptic properties and cooking losses of lamb. *J. Anim. Sci.* 42 (3), 575-583.
- Kenney, P.A., Goddard, M.E. & Thatcher, L.P., 1995. Genetic parameters for terminal sires estimated using data of progeny from Border Leicester X Merino ewes. *Aust. J. Agric. Res.* 46, 703-719.
- Kirton, A.H., Carter, A.H., Clarke, J.N., Sinclair, D.P., Mercer, G.J.K. & Duganzich, D.M., 1995. A comparison between 15 ram breeds for export lamb production 1. Liveweights, body composition, carcass measurements, and composition. *N. Z. J. Agric. Res.* 38, 347-360.
- Lawrie, R.A., 1998. *Lawrie's Meat Science*. 6th ed. Woodhead Publ. Ltd. Cambridge, England.
- McGeehin, B., Sheridan, J.J. & Butler, F., 2001. Factors affecting the pH decline in lamb after slaughter. *Meat Sci.* 58, 79-84.
- Metherell, J.A., 1984. Management and breeding policies for the use of the Booroola F gene for increased flock prolificacy. *Proc. N. Z. Soc. Anim. Prod.* 44, 37-40.
- Meyer, H.H., Haribaskar, S., Abdulkhaliq, A.M. & Thompson, J.M., 1998. Callipyge gene effects on lamb growth, carcass traits, muscle weights and meat characteristics. 6th World Congress on Genet. Applied to Livestock Prod. 25, 161-172.
- Morrison, W.R. & Smith, M.L., 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. *J. Lipid Res.* 5, 600-602.
- Olivier, J.J., 1999. The South African Merino performance testing scheme. In *Premium Quality Wool Symposium. Proc. Assoc. Advmnt. Anim. Breed. Genet.* 13, 119-124.

- Olivier, W.J., Snyman, M.A., Van Wyk, J.B. & Erasmus, G.J., 1998. Genetic parameter estimates for fitness traits in South African Merino sheep. *Livestock Prod. Sci.* 56, 71-77.
- Oman, J.S., Waldron, D.F., Griffin, D.B. & Savell, J.W., 1999. Effects of breed-type and feeding regimen on goat carcass traits. *J. Anim. Sci.* 77, 3215-3218.
- Ponzoni, R.W., Fleet, M.R., Walkley, J.R.W. & Walker, S.K., 1985. A note on the effect of the F gene on wool production and live weight of Booroola X South Australia Merino lambs. *Anim. Prod.* 40, 367-369.
- Priolo, A., Waghorn, G.C., Lanza, M., Biondi, L. & Pennisi, P., 2000. Polyethylene glycol as a means for reducing the impact of condensed tannins in carob pulp: Effects on lamb growth performance and meat quality. *J. Anim. Sci.* 78, 810-816.
- Sañudo, C., Sierra, I., Olleta, J.L., Martin, L., Campo, M.M., Santolaria, P., Wood, J.D. & Nute, G.R., 1998. Influence of weaning on carcass quality, fatty acid composition and meat quality in intensive lamb production systems. *Anim. Sci.* 66, 175-187.
- Schönfeldt, H.C., Naudé, R.T., Bok, W., Van Heerden, S.M. & Smit, R., 1993. Flavour- and tenderness-related quality characteristics of goat and sheep meat. *Meat Sci.* 34, 363-379.
- Stanford, K., Woloschuk, C.M., McClelland, L.A., Jones, S.D.M. & Price, M.A., 1997. Comparison of objective external carcass scores for prediction of lamb carcass quality. *Can. J. Anim. Sci.* 77, 217-223.
- Teixeira, A., Delfa, R. & Treacher, T., 1996. Carcass composition and body fat depots of Galego Bragançano and crossbred lambs by Suffolk and Merino Precoce sire breeds. *Anim. Sci.* 63, 389-394.
- Williams, A.J. & Thornberry, K.J., 1992. The skin of medium wool merino sheep and its relationship to wool production. *Proc. Aust. Soc. Anim. Prod.* 19, 138-141.
- Visscher, A.H., Dijkstra, M., Lord, E.A., Süß, R., Rösler, H-J., Heylen, K. & Veerkamp, R.F., 2000. Maternal and carrier effects of the Booroola gene on food intake, growth and carcass quality of male lambs. *Anim. Sci.* 71, 209-217.

Chapter 3

EFFECT OF DIVERGENT SELECTION FOR REARING ABILITY IN MERINOS ON *POST MORTEM* pH DECLINE MEASURED IN THE *M. LONGISSIMUS DORSI*

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ABSTRACT

Data of 20 Merino sheep (10 rams and 10 ewes) descendent from two selection lines (for and against multiple rearing ability) were used. The sheep were slaughtered at a commercial abattoir. After slaughter pH was measured at 45 min, 2, 4, 8, 10, 12, 16, 20, 24, 33 and 48 h *post mortem* on the right side of each carcass in the *m. longissimus dorsi* between the 1st and the 6th lumbar vertebrae. The *m. longissimus dorsi* between the 1st and the 6th lumbar vertebrae of the left side was used for meat-quality analyses. Analysis of the data was complicated by the fact that the same animal was recorded repeatedly resulting in individual data points being correlated; this was overcome by fitting a random effect for animal. Since a smooth linear trend was not expected, a random cubic spline was added to the analysis. The initial pH of H line animals tended to be higher than that from the L line animals. No differences in pH between lines were recorded 20 h post slaughter. At 48 h post slaughter the pH of the L line was higher. Higher initial pH indicated lower stress levels. The meat of H line animals was tougher than those of L line contemporaries (99.79±3.58 vs. 88.32±3.38 N per 1.27 cm diameter). There were no differences in the other meat-quality characteristics. From this investigation it is clear that selection for multiple rearing ability in Merino sheep resulted in a higher pH₄₅ and a lower ultimate pH, and meat with a tendency towards a higher shearing value.

Key words: Meat quality, Merino, pH, selection lines

INTRODUCTION

It has been shown that pH (which is a measure of glycolysis) can range from 6.85 to 6.05 in lamb carcasses 45 minutes after slaughter (McGeehin *et al.*, 2001). There are several factors such as (stress (Apple *et al.*, 1995), electrical stimulation (Chrystall *et al.*, 1984) and chilling temperature (Bowling *et al.*, 1978)) that affect the rate of pH decline. These factors do not account for all the

variation between animals during post-mortem pH decline. Animal factors such as sex, species, breed and age as well as season may also influence pH (McGeehin *et al.*, 2001).

Meat tenderness is linked to the rate of decrease of muscle pH. If the muscle pH is too high in the early hours after slaughter, then cold shortening can occur if the carcass temperature is lowered too quickly, causing toughening of the meat (Lawry, 1998). Electrical stimulation (ES) can be used to bring about a rapid reduction in muscle pH, thus avoiding the possibility of cold shortening. A potential problem exists if ES is applied to carcasses with a naturally fast rate of pH decrease. Abril *et al.* (2001) have shown that the pH of already fast glycolysing carcasses can be lowered too quickly resulting in a decline in meat tenderness. Maximum tenderness of meat is associated with an intermediate rate of glycolysis and not the high rate that is often obtained when electrical stimulation is used (Chrystall *et al.*, 1984).

Therefore, given the importance of the pH in the early hours after slaughter, it would be of great benefit for meat processors to know in advance how pH is likely to react post slaughter. With this knowledge processors could exercise some level of pH control using electrical stimulation. This would allow the introduction of rapid chilling systems to reduce evaporative weight losses without adversely affecting meat tenderness (McGeehin *et al.*, 2001).

In an investigation looking at slaughter traits in Merino lines that were divergently selected for multiple rearing ability there was a difference in initial pH between the lines (Cloete *et al.*, 2002). It was, however, impossible to investigate pH decline, since too few pH measurements were taken. The objective of this investigation was to determine whether divergent selection for and against multiple rearing ability in Merino sheep influenced post-mortem pH profiles.

MATERIALS AND METHODS

Data of 20 Merino sheep (10 rams and 10 ewes) were used. The rams and ewes (five from each line) descended from two selection lines: a high (H) and a low (L) line. The selection procedure of the lines has already been discussed (Cloete & Scholtz, 1998). The 20 sheep were randomly selected to represent the two different groups. All the sheep were weighed 48 h prior to being slaughtered at a commercial abattoir. The afternoon prior to slaughter all the animals were loaded and transported to the abattoir with the minimum of stress, the duration of the trip being 45 min. At the abattoir the sheep were rested for 18 h prior to slaughtering and provided with water *ad libitum*. Rams and ewes were kept in separate pens overnight. Just before slaughter the rams and ewes were penned together and slaughtered randomly. All the sheep were killed within five minutes. The sheep were slaughtered using standard South African techniques. After being electronically stunned (4 seconds at 200 Volts) the sheep were exsanguinated and the carcasses

hung to facilitate bleeding (Hopkins *et al.*, 1992). Dressing was completed 20 min *post mortem* and chilling began 1 h *post mortem* and the carcasses were hung in a random order in the cooler. No electrical stimulation of the carcasses was applied. Hot carcass weight was recorded 30 min *post mortem* (Sañudo *et al.*, 1998). One day after slaughter the carcasses were transported from the abattoir to a deboning facility where they were maintained in a cooler for another 24 h prior to sampling.

Instrumental measurements of meat quality were made on the *m. longissimus dorsi*. The pH and temperature were measured on each animal after carcass dressing, at 45 min, 2, 4, 8, 10, 12, 16, 20, 24, 33 and 48 h post slaughter. A CRISON pH meter (507) fitted with a CRISON electrode (Cat. 52-32) and a thermometer that allowed automatic adjustment for the temperature, was inserted directly into the meat. The pH meter was calibrated with standard buffers at pH 4.0 and pH 7.0 and recalibrated after measuring 10 animals. The pH was measured on the right side of each animal in the *m. longissimus dorsi* between the 1st and the 6th lumbar vertebrae, none of the pH and temperature measurements were taken at the exact same place. After 48 h in the cooler the sheep were weighed to determine cold carcass weight, and the backfat depth was taken at the 13th rib and between the 3rd and 4th lumbar vertebra, 25mm from the midline (Bruwer *et al.*, 1987). The *longissimus dorsi* muscle from the left side was dissected from the 1st to the 6th lumbar vertebrae and used for meat-quality analyses (Schönfeldt *et al.*, 1993). Two loin sub-samples (the first taken at the first lumbar vertebrae and the second, caudally adjacent to it) were taken for the determination of cooking loss, drip loss, colour (after blooming for 30 minutes) and meat tenderness (Honikel, 1998). The colour was evaluated by using a Color-guide 45°/0° colorimeter (BYK-Gardner, USA) to determine L*, a*, b*, C* and h values (Commission International de l'Eclairage, 1976), with L* indicating brightness, a* the red-green range, b* the blue-yellow range, C* the chroma and h the hue angle.

Tenderness of the meat was determined on the same sample used for cooking loss determination and was measured with a Warner-Bratzler shear force apparatus connected to an Instron using 1.27cm diameter samples in triplicate (Honikel, 1998). The measuring speed was 200.0 mm/min.

The analysis of the pH data was complicated by the fact that the same carcass was assessed repeatedly from 45 min post slaughter to 48 hours post slaughter. This had the effect that individual data points were not uncorrelated, as required by analysis of variance. This problem was overcome by fitting a random effect for animal. The intraclass correlation estimated from this analysis accounted for the fact that the same carcass was recorded repeatedly, and it had the added advantage that the repeatability for pH and temperature could be calculated, using standard

procedures (Turner & Young, 1969). With regard to the response in pH and temperature over time, a linear trend was fitted to the data. This trend was also interacted with different lines. Since a smooth linear trend was not expected, a random cubic spline was added to the analysis (Gilmour *et al.*, 1999). The spline was similarly interacted with selection line in preliminary analyses. Initially, random deviations from a smooth curve were also fitted, but it was insignificant ($P < 0.05$), and it was possible to drop it from the model without a change in the observed log likelihood. Means depicting changes in pH and temperature over the period post slaughter were predicted by ASREML (Gilmour *et al.*, 1999) and are depicted graphically. The other data, where only one observation was made on a specific carcass, were analysed according to a standard 2 (lines, H or L) x 2 (sexes, ram or ewe) factorial design.

RESULTS

From the results it was evident that the linear change of pH over time interacted ($P < 0.05$) with selection line. The pH values of H line sheep initially tended to be higher than that of their L line contemporaries (Figure 1). The difference between lines became smaller in absolute terms as the muscle pH values declined over time. No absolute line difference was observed by 20 hours *post mortem*, when pH stabilised at approximately 5.6 to 5.7. From this point onwards, pH values of H line animals tended to continue to decline. In this process the pH became lower than those of their L line contemporaries. The line difference was significant ($P < 0.05$) at 48 hours *post mortem*.

Repeatability estimates for pH and temperature were calculated, at 0.28 ± 0.09 and 0.24 ± 0.09 , respectively. The repeatability estimates for the various traits were medium to low. It was possible to predict subsequent pH and temperature measurements to an extent from early measurements.

With respect to carcass temperature (Figure 2), a similar conclusion was made. Carcass temperature initially dropped substantially until approximately 10 hours post slaughter. Then it stabilised at slightly above 0°C , before rising to approximately 5°C by 39 hours post slaughter. Subsequently carcass temperature tended to decline further. Initially temperature of the H line animals was higher ($P < 0.05$) than in the L line. This difference declined over time and no discernable difference was found by 36 hours post slaughter. The temperature of the H line carcasses tended to decrease to a lower value than that of their L line contemporaries.

Animals in the H line were 6.7% heavier ($P < 0.05$) than contemporaries in the L line, when expressed relative to the latter group (Table 1). A similar line difference of 10.8% was found for cold carcass weight ($P < 0.05$). Dressing percentage was 4.0% higher in H line animals, and they also tended to have a thicker fat cover at the 13th rib ($P < 0.05$). Cooking loss, drip loss and the

calorimetric parameters were independent of line ($P < 0.10$). Meat from H line animals was 13.0% tougher ($P < 0.05$) than that of L line contemporaries (Table 1).

Rams were 21.3% heavier ($P < 0.01$) than ewes at slaughter (Table 1). Corresponding sex differences were found for hot and cold carcass weight ($P < 0.05$), the hot and cold carcass weights of the ewes were lower than that of the rams. Rams had a lower ($P < 0.05$) dressing percentage than ewes. The only other sex differences were for the L^* colour parameter ($P < 0.05$), while the hue angle tended ($P < 0.10$) to be larger in rams than in ewes.

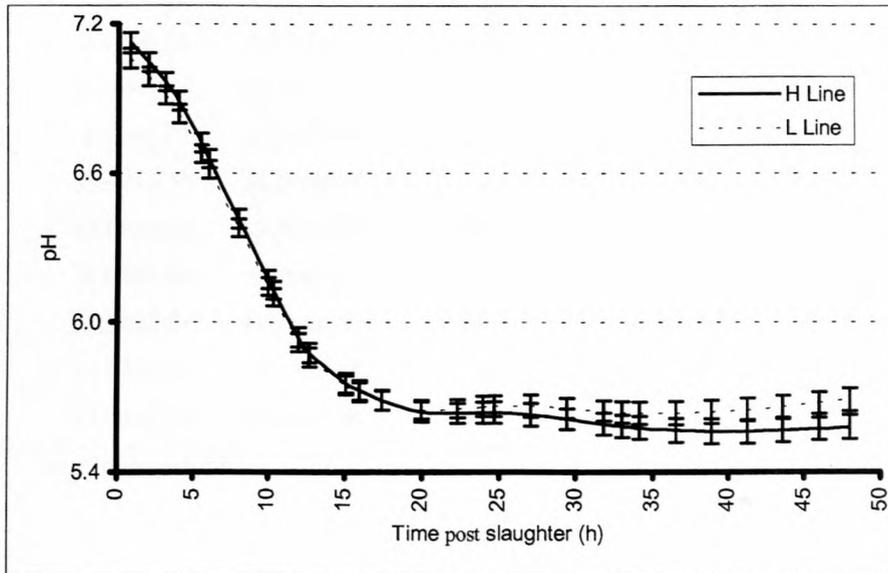


Figure 1. The decrease in muscle pH for Merino (selected for multiple rearing ability) carcasses over 48 hours.

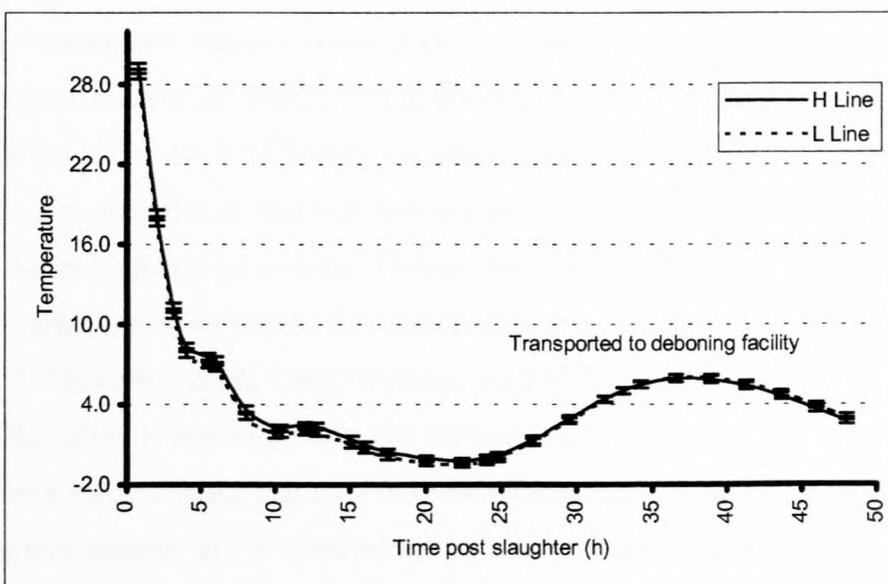


Figure 2. The temperature decline for the *m. longissimus dorsi* of Merino (selected for multiple rearing ability) carcasses over 48 hours.

Table 1. Slaughter and carcass traits of Merino lines divergently selected for and against multiple rearing ability.

Trait	Line			Sex		
	H line	L line	Significance	Ram	Ewe	Significance
Slaughter weight (kg)	41.16±1.13	38.56±1.07	*	43.70±1.07	36.03±1.14	**
Hot carcass weight (kg)	15.68±0.50	14.12±0.47	ns	15.79±0.47	14.01±0.50	**
Cold carcass weight (kg)	15.25±0.49	13.76±0.46	**	15.35±0.46	13.66±0.49	**
Dressing %	37.21±0.52	35.78±0.49	**	35.09±0.49	37.90±0.52	**
Fat depth 1 (mm)	0.63±0.11	0.52±0.10	*	0.52±0.10	0.63±0.11	ns
Fat depth 2 (mm)	0.99±0.14	0.95±0.14	ns	1.01±0.14	0.93±0.14	ns
Cooking loss %	32.04±0.91	31.85±0.86	ns	32.90±0.86	30.98±0.91	ns
Drip loss %	0.90±0.10	0.98±0.09	ns	0.86±0.09	1.02±0.10	ns
Colour L*	33.99±0.50	34.40±0.48	ns	35.10±0.48	32.28±0.50	**
a*	14.07±0.39	13.97±0.36	ns	13.77±0.36	14.28±0.39	ns
b*	8.87±0.36	8.50±0.34	ns	9.05±0.34	8.32±0.36	ns
Hue angle	32.23±1.06	31.31±1.00	ns	33.31±1.0	30.24±1.06	*
Chroma	16.67±0.43	16.37±0.41	ns	16.49±0.41	16.35±0.43	ns
Tenderness (N)	99.79±3.58	88.32±3.38	**	97.42±3.38	90.70±3.58	ns

* P<0.10 ** P<0.05 ns. Not significant

DISCUSSION

Results regarding line and sex differences from the present study were consistent with those reported in a previous study (Cloete *et al.*, 2002). It would serve no purpose to elaborate on these findings, except to state that the present line differences in favour of the H line in live weight, carcass weight and dressing percentage confirm previous results. The trend that was reported in the previous investigation (Cloete *et al.*, 2002), where the H line animals tended to have tougher meat (127.9±7.24N) than the L line (113.0±7.24N), manifested itself as significant in this investigation (Table 1). A possible explanation is that this investigation was designed to standardise the stress, which resulted in the minimising of external factors that could influence toughness, resulting in smaller within line variations being noted. Sex differences were consistent with those found in the literature (Purchas, 1978; Kirton *et al.*, 1982; Wylie *et al.*, 1997).

The higher pH₄₅ of the H line animals in the previous study (Cloete *et al.*, 2002) and a similar tendency in the present study suggest that they may have been less susceptible to stress just prior to slaughter. Postmortem muscle pH is determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis. This would be curtailed if glycogen is depleted by fatigue or fear in the animal just prior to slaughter, which will lower initial pH (Lawrie, 1998). The

contention regarding lower susceptibility to stress could not be validated, since no stress measurements were recorded. It should, however, be stated that the two lines were slaughtered at random. A faster-working pre-slaughter metabolism (stress causes an increase in the metabolic rate) would continue after slaughter. This may account for the lower initial pH and subsequent fast glycolysis in the L line Merinos (McGeehin *et al.*, 2001).

Muscle with a lower initial pH because of a deficiency of glycogen at death (L line) also lacks the glucose which is produced by amylolysis after slaughter. Such muscle may end up with a higher ultimate pH (Lawrie, 1998). Higher ultimate pH levels are conducive to microbial growth and thus the susceptibility of meat to microbial spoilage (Gill & Reichel, 1989).

A rapid muscle pH decline would result in tougher meat (Bruce *et al.*, 2001). Hertzman *et al.* (1993) confirmed that lower ultimate muscle pH values increased shear force. This may explain why the meat of the H line animals was tougher ($P < 0.05$) than that of their L line contemporaries. The higher initial muscle temperature of the H line Merinos (Figure 2) correlates with the tendency towards a thicker fat cover at the 13th rib of the H line Merinos (Table 1). Fat acts as an insulator for the carcass, which may have resulted in the carcasses of the H line Merino sheep taking longer to cool (Bruce & Ball, 1990). The fact that the carcasses were transported from the abattoir to the deboning facility 25 hours post slaughter could explain the increase in muscle temperature during that period (Figure 2).

CONCLUSION

From the results in Figure 1 and the discussion presented above it is contended that H line animals were less susceptible to stress in the pre-slaughter phase than their L contemporaries. In this regard it is appropriate to refer to the results published by Lindsay (1996) wherein Merinos were divergently selected for temperament. This selection regime resulted in a flighty, nervous line and a line that was relatively unresponsive to external stimuli. The lamb survival rate of the latter line was found to be markedly higher ($P < 0.05$) than that in the former line. At this stage it is unclear whether the results obtained in the present study are related to those of Lindsay (1996). Further investigations into this matter are indicated.

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REFERENCE

- Abril, M., Campo, M.M., Önenç, A., Sañudo, C., Albertí, P. & Negueruela, A.I., 2001. Beef colour evolution as a function of ultimate pH. *Meat Sci.* 58, 69-78.
- Apple, J.K., Dikeman, M.E., Minton, J.E., McMurphy, R.M., Fedde, M.R., Leith, D.E. & Unruh, J.A., 1995. Effects of restraint and isolation stress and epidural blockade on endocrine and blood metabolite status, muscle glycogen metabolism, and incidence of dark-cutting longissimus muscle of sheep. *J. Anim. Sci.* 73, 2295-2307.
- Bowling, R.A., Smith, G.C., Dutson, T.R. & Carpenter, Z.L., 1978. Effects of pre-rigor conditioning treatments on lamb muscle shortening, pH and ATP. *J. Food Sci.* 43, 502-507.
- Bruce, H.L. & Ball, R.O., 1990. Postmortem interaction of muscle temperature, pH and extension on beef quality. *J. Anim. Sci.* 64, 4167-4175.
- Bruce, H.L., Scott, J.R. & Thompson, J.M., 2001. Application of an exponential model to early postmortem bovine muscle pH decline. *Meat Sci.* 58, 39-44.
- Bruwer, G.G., Naude, R.T. & Vosloo, W.A., 1987. An evaluation of the lamb and mutton carcass grading system in the Republic of South Africa. 1. A survey of carcass characteristics of the different grades. *S. Afr. J. Anim. Sci.* 17, 79-84.
- Chrystall, B.B., Devine, C.E., Ellery, S. & Wade, L., 1984. Low voltage electrical stimulation of lamb: its effect on muscle pH and tenderness. *N. Z. J. Agric. Res.* 27, 513-523.
- Cloete, J.J.E., Cloete, S.W.P., Hoffman, L.C. & Fourie, J.E., 2002. Slaughter traits in Merino lines divergently selected for multiple rearing ability. *S. Afr. J. Anim. Sci.* (Submitted).
- Cloete, S.W.P. & Scholtz, A.J., 1998. Lamb survival in relation to lambing and neonatal behavior in medium wool Merino lines divergently selected for multiple rearing ability. *Aust. J. Exp. Agric.* 38, 801-811.
- Commission International De L' Eclairage, 2nd, 1976. Commission Internationale De L' Eclairage, 18th session, London, England. September 1975. CIE publication No. 36.
- Gill, C. & Reichel, M., 1989. Growth of the cold-tolerant pathogens *Yersinia enterocolitica*, *Aeromonas hydrophila* and *Listeria monocytogenes* on the high pH beef packaged under vacuum or carbon dioxide. *Food microbiol.* 6, 223-230.
- Gilmour, A.R., Cullis, J.J., Welham, S.J. & Thompson, R., 1999. ASREML-Reference manual. NSW Agriculture Biometric Bulletin No. 3. NSW Agriculture Institute, Forest Road, Orange 2800, NSW, Australia.

- Hertzman, C., Olsson, U. & Tornberg, E., 1993. The influence of high temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscle. *Meat Sci.* 35, 119-141.
- Honikel, K.O., 1998. Reference methods for the assessment of physical characteristics of meat. *Meat Sci.* 49, 447-457.
- Hopkins, D.L., K.D., Pirlot, K.L. & Roberts, A.H.K., 1992. Elliotdale and crossbred lambs: growth rate, wool production, fat depth, saleable meat yield, carcass composition and muscle content of selected cuts. *Aust. J. Exp. Agric.* 32, 429-434.
- Kirton, A.H., Clarke, J.N. & Hickey, S.M., 1982. A comparison of the composition and carcass quality of Kelly and Russian castrate, ram, wether and ewe lambs. *Proc. N. Z. Soc. Anim. Prod.* 42, 17-118.
- Lawrie, R.A., 1998. *Lawrie's Meat Science*. 6th ed. Woodhead Publ. Ltd. Cambridge, England.
- Lindsay, D.R., 1996. Environmental and reproductive behavior. *Anim. Rep. Sci.* 42, 1-12.
- McGeehin, B., Sheridan, J.J. & Butler, F., 2001. Factors affecting the pH decline in lamb after slaughter. *Meat Sci.* 58, 79-84.
- Purchas, R.W., 1978. Some effects of nutrition and castration on meat production from male Suffolk cross (Border Leicester-Romney cross) lambs. 1. Growth and carcass quality. *N. Z. J. Agric. Res.* 21, 370-376.
- Sañudo, C., Sierra, I., Ollete, J.L., Martin, L., Campo, M.M., Santolaria, P., Wood, J.D. & Nute, G.R., 1998. Influence of weaning on carcass quality, fatty acid composition and meat quality in intensive lamb production systems. *Anim. Sci.* 66, 175-187.
- Schönfeldt, H.C., Naudè, R.T., Bok, W., Van Heerden, S.M. & Smit, R., 1993. Flavour- and tenderness-related quality characteristics of goat and sheep meat. *Meat Sci.* 34, 363-379.
- Turner, H.N. & Young, S.S.Y., 1969. *Quantitative Genetics in Sheep Breeding*. Macmillan South Africa (Publishers) PTY LTD, Jorrison Street, Johannesburg.
- Wylie, A.R.G., Chestnutt, D.M.B. & Kilpatrick, D.J., 1997. Growth and carcass characteristics of heavy slaughter weight lambs: effects of sire breed and sex of lamb relationship to serum. *Anim. Sci.* 64, 309-318.

Chapter 4

COMPARATIVE ANALYSIS OF CARCASS CHARACTERISTICS BETWEEN SA MUTTON MERINO AND MERINO EWES WITH INCREASING AGE

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ABSTRACT

Slaughter data of 653 Merino and South African Mutton Merino (SAMM) ewes were analysed. Animals were between 220 and 2719 days of age at slaughter, and encompassed a range of slaughter weights from 27 to 100 kg. The ewes were differentiated according to age, 219 ewes being younger than 600 days and 416 being older than 600 days at slaughter. Recordings included cold carcass weight, dressing percentage and fat depth between the 3rd and 4th lumbar vertebra, 25 mm from the midline. Young SAMM ewes had 10% heavier carcass weights than young Merino ewes and mature SAMM ewes had 47% heavier carcass weights than Merinos. The maximum mean carcass weights for both breeds were 33.44 and 22.65kg for the SAMM and Merino respectively. Mature SAMM ewes had a 47% thicker fat depth between the 3rd and 4th lumbar vertebra than Merino ewes. The Merino is known to be a leaner breed, which does not reach the high fat levels of the SAMM.

Key words: Carcass, fat depth, Merino, SAMM, slaughter

INTRODUCTION

Throughout the world sheep are important meat-producing animals (Kirton *et al.*, 1995). The most important components of ewe productivity are the total weight of lamb produced, body weight at culling and, in the case of wool-producing sheep, the amount and quality (mainly determined by fibre diameter) of the wool. From 65 to 88% of the total income from wool sheep is derived from mutton, while it is even higher in the case of mutton sheep (Hoon *et al.*, 2000). In South Africa, Merino sheep are better known for their wool production, whilst SA Mutton Merino (SAMM) sheep are better known for their mutton production. In a study by Fourie & Cloete (1993) the mean number of lambs marked, as a percentage of ewes joined, was 87.7% for Merino

and 112.7% for SAMM. The objective of this study was to compare the mutton-production attributes of Merino and SAMM ewes when slaughtered at different ages. Slaughter age varied between approximately 7 months and 7.5 years.

MATERIALS AND METHODS

Data of 635 commercial Merino and SAMM ewes routinely slaughtered at the Langgewens experimental farm near Mooresburg in the Swartland during 1994-1998 were evaluated. The animals were between 220 and 2719 days of age at slaughter and encompassed a range of slaughter weights from 27 to 100 kg. The ewes were differentiated according to age, 219 ewes being younger than 600 days and 416 being older than 600 days at slaughter. The young group of ewes would be classified as A-age group (no permanent incisors - Bruwer *et al.*, 1987) and AB-age group (1 to 2 permanent incisors) (Livestock Marketing, 2001) in the meat industry, while the older ewes would achieve B- and C-age groups (3 and more permanent incisors - Bruwer *et al.*, 1987). Prior to slaughter the live weight of the sheep was determined. Recordings on the carcasses included cold carcass weight, dressing percentage and the fat depth between the 3rd and 4th lumbar vertebra, 25 mm from the midline (Bruwer *et al.*, 1987).

In a preliminary analysis, Merino and SAMM ewes were compared for slaughter traits in a 2x2 factorial design, with breed and slaughter age as factors. Least-squares procedures were used for this purpose to account for uneven subclasses (Harvey, 1990). Carcass weight, dressing percentage and fat depth means were regressed on slaughter weight and slaughter age, fitting linear or quadratic response curves where appropriate. The inclusion of slaughter weight as a continuous independent variable accounted for the variation caused by slaughter age, which was excluded from further analyses. Equations computed for Merino and SAMM ewes were tested for significant differences.

RESULTS

Young SAMM ewes had 10% heavier ($P<0.01$) carcass weights than their Merino contemporaries, while this difference amounted to 47% ($P<0.01$) in the mature SAMM ewes compared with mature Merino ewes (Table 1). No significant difference between the breeds was observed for dressing percentage and fat depth in young animals. The dressing percentage and fat depth of mature SAMM were respectively 4% and 52% higher ($P<0.05$) than that of their Merino contemporaries (Table 1). An initial breed X age group interaction ($P<0.05$) in the preliminary analysis was reduced to insignificance ($P>0.20$) by the inclusion of the linear and quadratic effects of slaughter age. This interaction was apparently caused by young Merino ewes being slaughtered

at a later age compared to SAMM ewes to obtain higher slaughter weights. Breed-specific regressions for carcass weight and fat depth on slaughter age differed between breeds (Figure 1 and Table 2). The linear tendencies did not differ significantly ($P>0.20$) between the breeds in the case of dressing percentage. Quadratic regressions differed between breeds in all instances ($P<0.05$). After reaching a maximum carcass weight, SAMM ewes showed a clear decrease in dressing percentage with increase in age (Figure 2), and in Figure 3 there is a concomitant decrease in fat depth with increasing age.

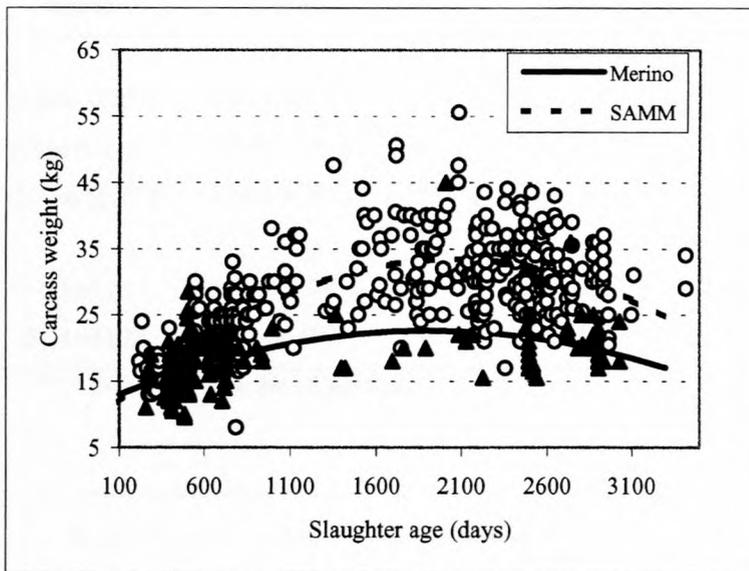


Figure 1. Regressions of carcass weight on slaughter age for Merino (\blacktriangle) and SAMM (\circ) ewes

Table 1. Slaughter traits (SE) for young and old Merino and SA Mutton Merino (SAMM) ewes

Age group	Young ewes		Mature ewes		Significance of		
Breed	Merino	SAMM	Merino	SAMM	Age	Breed	Age X Breed [#]
Number	148	71	92	324			
Trait:							
Carcass weight (kg)	15.9±0.5	17.7±0.7	20.2±0.6	29.7±0.3	**	**	**
Dressing %	40.7±0.4	40.3±0.5	42.8±0.5	44.7±0.3	**	0.7	**
Fat depth (mm)	3.1±0.3	2.5±0.4	4.4±0.3	6.7±0.3	**	**	**

[#] -Interaction between age and breed

** -Significant ($P<0.01$)

Merino and SAMM ewes did not differ as far as the linear or quadratic regressions of dressing percentage on slaughter weight were concerned (Figure 4). An average linear increase ($P<0.05$)

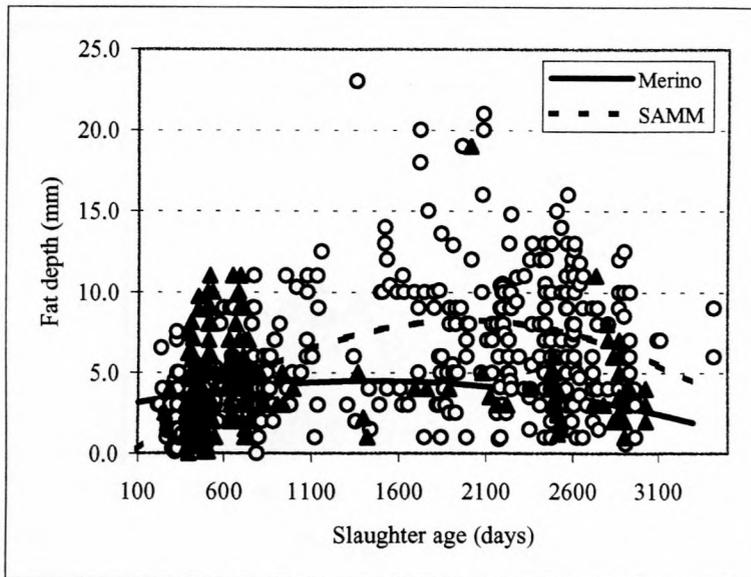


Figure 3. Regressions of fat depth on slaughter age for Merino (▲) and SAMM (○) ewes.

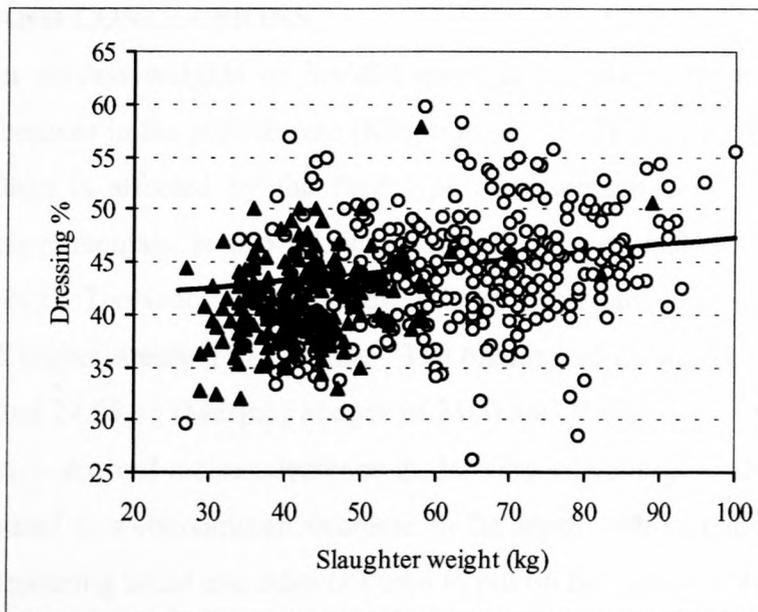


Figure 4. Regression of dressing percentage on slaughter weight in Merino (▲) and SAMM (○) ewes

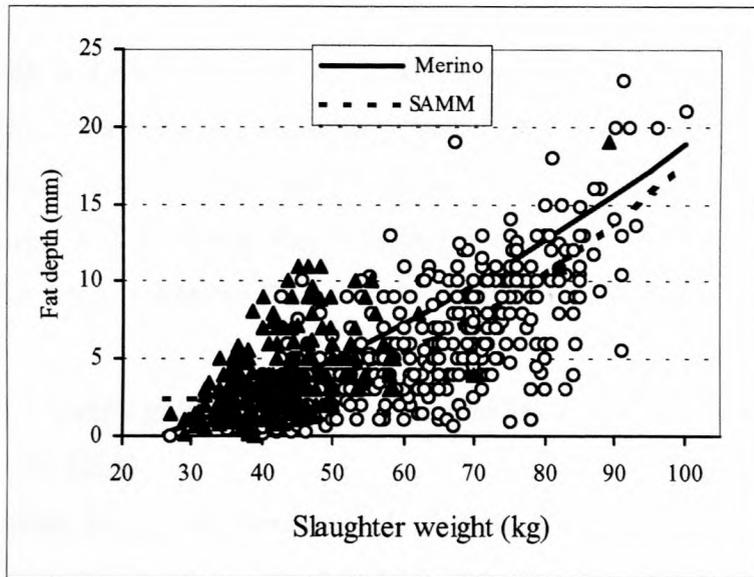


Figure 5. Regression of fat depth on slaughter weight in Merino (\blacktriangle) and SAMM (\circ) ewes.

DISCUSSION AND CONCLUSIONS

The heavier carcass weights of SAMM ewes at the same age as Merino ewes could be attributed to differences in the growth rate (Kirton *et al.*, 1995) and mature size of the two breeds. Dressing percentage is affected by the feed type and stomach content when live weights are recorded. Dressing percentage is also known to increase with animal weight and degree of fatness (Kirton *et al.*, 1995). The mature SAMM ewes were fatter and heavier than the Merino ewes, resulting in a 4% higher dressing percentage. The breeds had mean maximum carcass weights of 33.44 (SAMM) and 22.65 kg (Merino) at ages of 2100 and 1900 days (Figure 1). The tendency of SAMM ewes which showed a clear decrease in dressing percentage with increase in age (Figure 2), may be attributed to a concomitant decrease in fat depth with increasing age (Figure 3). The SAMM is a late maturing breed and does not tend to put on fat quickly (Neser *et al.*, 2000), but the Merino is a leaner breed and does not reach the high fat levels of the SAMM ewes (Figure 3). It is also known that as sheep get older they tend to lose condition. These results emphasise the fact that the SAMM is likely to render a heavier but possibly fatter carcass than the Merino at the same age.

REFERENCES

- Bruwer, G.G., Naude, R.T. & Vosloo, W.A., 1987. An evaluation of the lamb and mutton carcass grading system in the Republic of South Africa. 1. A survey of carcass characteristics of the different grades. *S. Afr. J. Anim. Sci.* 17, 79-84.
- Fourie, A.J. & Cloete, S.W.P., 1993. Reproductive performance of commercial Merino, Dohne Merino and SA Mutton Merino flocks in the Southern Cape. *S. Afr. J. Anim. Sci.* 23, 104-110.
- Harvey, W.R., 1990. 'User's guide for LSMLMVV and MIXMDL.' PC-2 version. (Mimeograph: Columbus, Ohio, USA).
- Hoon, J.H., Herselman, M.J., Van Heerden, M. & Pretorius, A.P., 2000. The effect of bypass protein supplementation on the reproductive performance of Merino sheep grazing mixed karoo veld. *S. Afr. J. Anim. Sci.* 30, 60-61.
- Kirton, A.H., Carter, A.H., Clarke, J.N., Sinclair, D.P., Mercer, G.T.J.K. & Duganzich, D.M., 1995. A comparison between 15 ram breeds for export lamb production 1. Liveweights, body composition, carcass measurements, and composition. *N.Z. J. Agric. Res.* 38, 347-360.
- Neser, F.W.C., Erasmus, G.J. & Van Wyk, J.B., 2000. Genetic studies on the South African Mutton Merino: growth traits. *S. Afr. J. Anim. Sci.* 30 (3), 172-177.
- Livestock Marketing, 2001. <http://www.nda.agric.za/docs/MarketExtension/7Livestock.pdf>.

Chapter 5

A COMPARISON BETWEEN THE CARCASS COMPOSITION, RETAIL CUTS, BACKFAT DEPTH AND CHEMICAL COMPOSITION OF SA MUTTON MERINO AND DORMER SHEEP

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ABSTRACT

The carcass composition, retail cuts and chemical composition of 61 Dormer (21 rams and 40 ewes) and 35 South African Mutton Merinos (SAMM) (17 rams and 18 ewes) were used. A range of carcass measurements was recorded. As there was no sex x breed interaction, the data were pooled to present the main effects of breed and sex. There were no differences in slaughter and carcass weight between Dormer and SAMM sheep at 18 months of age. The Dormer had a higher fat content (kidney fat, backfat depth) than the SAMM. The eye-muscle area of the Dormers was 13% larger than that of the SAMM sheep. Rams were heavier (64.86 ± 0.85 vs. 44.55 ± 0.74 kg) than the ewes at slaughter. All the traits measured indicated advantages ($P < 0.05$) in favour of rams. After adjustment for the higher live weight of the rams, the proportion of neck retail cut from the rams was higher ($P < 0.05$) than from the ewes. The proportion of hindquarter weight from ewes was correspondingly higher ($P < 0.05$). After adjustment for the higher live weight of the rams the moisture (75.35 ± 0.37 vs. $73.35 \pm 0.37\%$) and lipid (2.68 ± 0.33 vs. $3.80 \pm 0.33\%$) contents differed significantly ($P < 0.05$) between the rams and ewes. The only significant differences in fatty acids were the SFA fatty acids and MUFA fatty acids that differed between the Dormer and SAMM sheep ($P < 0.05$). According to the fatty acid profile, Dormer meat is slightly healthier than that of SAMM sheep.

Key words: Carcass, Dormer, meat yield, muscle composition, SAMM, sex

INTRODUCTION

Consumers are demanding leaner cuts of lamb and leanness has thus become an important breeding objective for slaughter lamb production (Gilmour *et al.*, 1994). In the sheep industry production costs are high and profit margins are small at all stages. If economic production and

consumption are to be maintained, attention needs to be paid to improvement in meat quality (Sañudo *et al.*, 1998).

The South African Mutton Merino (SAMM) is a dual-purpose (mutton and wool) sheep breed which was developed from the imported German Merino. The breed has a high growth rate and produces a slaughter lamb with good meat quality attributes. (Neser *et al.*, 2000). The Dormer is a breed that was developed at Elsenburg experimental farm from the Dorset Horn and German Merino breeds. The principal objective with the development of the Dormer was to provide a terminal sire breed for crossbreeding on Merino ewes (Van der Merwe, 1976). The Dormer is an early maturing breed and tends to gain fat easily, whilst the SAMM sheep is a late-maturing breed that gains fat at a later age (Neser *et al.*, 2000). When lambs are slaughtered at the same age, the SAMM should have less fat than the early-maturing Dormer.

The effects of breed, age and live mass on the carcass composition and retail cuts of meat-type lambs have been studied (Hopkins *et al.*, 1992). Jeremiah *et al.* (1997) found that at the same age rams were more developed in the neck and head area than ewes. Ewes were more developed in the hindquarters (Fahmy *et al.*, 1999). Despite the difference in growth rate, rams yielded lower carcass weights than ewes at an equal slaughter weight due to greater head weight and the weight of the testes (Purchas, 1978). Rams deposit less total carcass fat and have smaller individual fat depots than ewes at the same age (Kirton *et al.*, 1995).

No results pertaining to comparative slaughter traits in the two breeds were found in the literature. This paper examines the effect of breed and sex on the carcass composition, yield of retail cuts, fat depth and chemical composition of the meat from SAMM and Dormer sheep.

MATERIAL AND METHODS

Data were obtained from 61 (21 rams and 40 ewes), 18-month-old Dormer and 35 (17 rams and 18 ewes) 18-month-old SAMM sheep reared at Elsenburg experimental farm. The ewes of both breeds were maintained in the same flock from birth until slaughter, as were the rams. Both groups were subjected to the same level of husbandry (e.g. parasite control, weaning period). All sheep were kept on irrigated pasture consisting of clover, kikuyu, lucerne and oats in winter and predominantly kikuyu during the summer months. An energy lick consisting of 50% maize, 25% bone meal and 25% salt was provided. From four weeks of age until weaning at 14 weeks, all lambs received commercial lamb creep feed pellets. A drenching and inoculation programme as prescribed by the State Veterinarian was followed (Van Wyk *et al.*, 1993).

Live weight was determined 24 hours prior to slaughter. The sheep were slaughtered at a commercial abattoir using standard South African techniques. After being electronically stunned (4

seconds at 200 Volts) the sheep were exsanguinated and the carcasses hung to bleed. After dressing, the carcasses were hung in a cooler at 2°C for 48 hours.

Recordings on the carcass included the weight of carcass components, cold carcass weight (after 24 hours in a cooler at 2°C), the weight of different retail cuts and backfat depth. The latter was measured at a site 25 mm off the midline at the 13th rib (Gilmour *et al.*, 1994). Carcass components that were weighed included the head, trotters and skin. The thickness of the skin was measured at the same site as backfat depth. Carcass length was measured on the hanging carcass from the pubis bone to the front of the first rib. The leg circumference was measured at two points: the first leg circumference (1) was taken at the maximum circumference of a line passing over the distal end of the iliac wings of the pelvis and the most caudal point on the median line between the legs (Stanford *et al.*, 1997), and the second leg circumference (2) was taken at the stifle (Oman *et al.*, 1999). Hind leg length was measured from the inner edge of the proximal end of the tibia to the anterior tip of the pubis (Enright, 1990). The eye-muscle area was also measured at the 13th rib (Gilmour *et al.*, 1994). This was done by tracing the eye-muscle circumference onto wax paper. The silhouette of the eye muscle was then passed through a Li Cor LI3100 (1 mm² resolution) for determination of surface area. Each silhouette was measured in 5 fold and the mean used in the statistical analysis.

After 48 hours in the cooler the carcasses were partitioned into South African retail cuts which were weighed separately. These cuts consisted of the neck, shoulder, chuck, flatrib, prime rib, loin and hindquarters. The neck was removed at the seventh cervical vertebrae (the point where the neck starts bending), the cut being made at right angles to the spine. Thereafter the hind legs were removed. This consisted of loosening the flanks on the inside of the legs (following the curve of the leg muscle) to an imaginary line perpendicular to the ilium (seen from the inside of the carcass). The leg was then removed by cutting along this line, just missing the ilium (through the last lumbar vertebrae). The rest of the carcass was then halved prior to being separated into trade retail cuts. The shoulder was removed by sawing along an imaginary line from the elbow joint to a point below the spinal column, between the fifth and sixth ribs. The carcass was then swivelled so that the spinal column was sawn through at right angles. The flank was removed by sawing from the *obliquus abdominis internus* muscle parallel to the spine. The loin and rib were separated perpendicularly to the spinal column at the junction of the thoracic and lumbar vertebrae. All commercial cuts were weighed on a digital computing scale, which measures to the nearest gram (Hoffman, 2000).

The 11/13th-rib cut from the right side of the carcass from 24 SAMM (12 rams and 12 ewes) and 24 Dormer (12 rams and 12 ewes) that were randomly selected, was removed. The *m.*

longissimus dorsi was dissected, minced, freeze dried and analysed for proximate chemical composition as follows: the protein by a FP-428 Nitrogen and Protein Determinator (Leco). Lipid (petroleum ether extraction) was measured according to ALASA (1995). Moisture content was determined by drying a sample (± 1.0 g) at 100°C to a constant weight and ash content, ashing at 500°C overnight (ALASA, 1995).

Fatty acid methyl esters (FAME) were prepared according to the method of Morrison & Smith (1964). The FAME analysed with a GLC: Varian Model 3300, equipped with flame ionisation detection and two 30 m fused silica megabore DB-225 columns of 0.53 internal diameter (J&W Scientific Folsom, CA). Gas flow rates were: hydrogen, 25 ml/min; air, 250 ml/min; and nitrogen (carrier gas), 5-8 ml/min. Temperature programming was linear at $4^{\circ}\text{C}/\text{min}$; initial temperature, 160°C ; final temperature, 220°C held for 10 min; injector temperature, 240°C ; and detector temperature, 250°C . The FAME was identified by comparison of the retention times of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Prior to testing for differences of the various parameters between the two breeds and sexes, a least square analysis of variance was done according to a 2 (breed, SAMM and Dormer) x 2 (sex, male and female) factorial design to account for uneven subclasses. The ASREML programme was used for this purpose (Gilmour *et al.*, 1999). There was no significant interaction between sex and breed. The differences between the various parameters determined for the two breeds and between sexes were tested separately by means of the null hypothesis (H_0) with $H_0: \mu = \mu_0$ and the alternative hypothesis (H_a) being $H_a: \mu \neq \mu_0$. This was done by means of contrast analysis and estimated least square means (\pm SE) as reported in the tables. Differences between the variables were accepted as being significant if the possibility of rejection of H_0 was equal to or less than 5% ($P \leq 0.05$), and highly significant if equal to or less than 1% ($P \leq 0.01$) for the two breeds and sexes.

RESULTS

As there was no sex x breed interaction, least square means depicting the main effects of breed and sex were tabulated. The means (\pm SE) of the various parameters measured are shown in Table 1. Although there was no difference in mean slaughter and carcass weights between the two breeds, the Dormers had a 6% ($P < 0.01$) higher dressing percentage.

The mean skin weight of the SAMM sheep was heavier ($P < 0.01$) than that of the Dormers. Similarly the trotters of the SAMM were 5% heavier ($P < 0.01$) than those of Dormers. The mean carcass ($P < 0.05$) and hind leg length ($P < 0.01$) of the SAMM were longer than those of the Dormer sheep. The Dormers had a greater mean carcass width ($P < 0.01$) than their SAMM contemporaries.

The kidneys of the SAMM sheep were heavier ($P < 0.01$) than those of the Dormers but the livers of Dormer sheep were heavier ($P < 0.05$) than those of the SAMM sheep. The kidney fat ($P < 0.05$) and fat depth ($P < 0.01$) of the Dormer sheep were heavier and thicker than those of SAMM sheep. Mean shoulder, flatrib and loin retail cut weights were generally higher in Dormers than in SAMM sheep, but the neck retail cut weight of the SAMM was significantly heavier ($P < 0.01$). The mean eye-muscle area of the Dormers was 13% larger ($P < 0.01$) than those of the SAMM sheep (Table 1).

Mean slaughter weight of the rams (pooled breeds) was 45% heavier ($P < 0.01$) than that of the ewes. A corresponding difference ($P < 0.01$) of 44% was found for carcass weight between sexes. In almost all the other traits that were measured means for rams were higher ($P < 0.01$) than those of ewes. No sex difference was observed in only two traits, namely the kidney fat and fat depth 25mm from the midline at the 13th rib (Table 1).

There were no differences between the mean proximate chemical composition of the 11/13th-rib cut (*m. longissimus dorsi*) of SAMM and Dormer sheep (Table 2). The protein ($P < 0.05$), lipid ($P < 0.05$) and ash ($P < 0.01$) contents of meat from ewes were higher than those of rams (Table 2).

After adjustment for the higher live weight of the rams by analysis of covariance, some of the carcass traits still differed ($P < 0.05$) between the sexes (Table 3). The difference in adjusted carcass weight remained in favour ($P < 0.01$) of the ewes. The mean carcass length, leg circumference (2) and carcass width of the ewes were significantly higher ($P < 0.01$) after adjustment for live weight. The eye-muscle areas and fat depth 25 mm from the midline were generally higher in the ewes after adjustment for live weight (Table 3).

Table 1. Mean (\pm SE) of various carcass yields and commercial retail cuts yields of SAMM and Dormer rams and ewes.

Trait	Breed			Sex		Significance
	SAMM	Dormer	Significance	Ram	Ewes	
<u>Number</u>	35	61		38	58	
<u>Carcass characteristics</u>						
Slaughter weight (kg)	54.22 \pm 0.88	55.20 \pm 0.70	n.s.	64.86 \pm 0.85	44.55 \pm 0.74	**
Carcass weight (kg)	22.51 \pm 0.51	24.5 \pm 0.41	n.s.	27.75 \pm 0.48	19.25 \pm 0.43	**
Dressing %	41.52 \pm 0.38	44.23 \pm 0.30	**	42.68 \pm 0.37	43.06 \pm 0.32	n.s.
Skin weight (kg)	4.99 \pm 0.10	4.17 \pm 0.08	**	5.52 \pm 0.09	3.64 \pm 0.08	**
Skin thickness (kg)	2.22 \pm 0.05	2.20 \pm 0.04	n.s.	2.38 \pm 0.05	2.04 \pm 0.04	**
Head (kg)	3.05 \pm 0.04	2.88 \pm 0.03	**	3.51 \pm 0.04	2.42 \pm 0.03	**
Trotters (kg)	1.17 \pm 0.02	1.11 \pm 0.12	**	1.34 \pm 0.02	0.94 \pm 0.01	**
Testes (kg)	0.62 \pm 0.03	0.58 \pm 0.02	n.s.			
Carcass length (cm)	78.03 \pm 0.47	77.48 \pm 0.38	*	80.53 \pm 0.45	74.99 \pm 0.40	**
Carcass depth (cm)	30.64 \pm 0.19	30.67 \pm 0.16	n.s.	32.33 \pm 0.19	28.97 \pm 0.16	**
Carcass width (cm)	25.28 \pm 0.28	26.82 \pm 0.22	**	27.57 \pm 0.27	24.54 \pm 0.24	**
Leg length (cm)	28.14 \pm 0.22	27.01 \pm 0.18	**	28.29 \pm 0.21	26.86 \pm 0.19	**
Leg circumference (1) (cm)	43.06 \pm 0.44	44.1 \pm 0.35	n.s.	46.01 \pm 0.42	41.14 \pm 0.37	**
Leg circumference (2) (cm)	28.08 \pm 0.3	28.17 \pm 0.24	n.s.	28.83 \pm 0.29	27.42 \pm 0.25	**
Eye muscle area (cm ²)	12.99 \pm 0.38	15.11 \pm 0.31	**	15.77 \pm 0.37	12.33 \pm 0.32	**
Fat depth (mm)	1.20 \pm 0.11	1.62 \pm 0.09	**	1.50 \pm 0.11	1.31 \pm 0.09	n.s.
<u>Organs</u>						
Kidney (kg)	0.16 \pm 0.003	0.15 \pm 0.02	**	0.19 \pm 0.03	0.12 \pm 0.02	**
Heart (kg)	0.29 \pm 0.01	0.29 \pm 0.01	n.s.	0.34 \pm 0.01	0.24 \pm 0.01	**
Liver (kg)	0.99 \pm 0.02	1.13 \pm 0.02	*	1.37 \pm 0.02	0.75 \pm 0.02	**
Lungs (kg)	0.81 \pm 0.01	0.85 \pm 0.01	n.s.	1.00 \pm 0.01	0.65 \pm 0.01	**
Spleen (kg)	0.09 \pm 0.003	0.10 \pm 0.003	n.s.	0.12 \pm 0.003	0.07 \pm 0.003	**
Kidney fat (kg)	0.23 \pm 0.03	0.29 \pm 0.02	*	0.27 \pm 0.02	0.25 \pm 0.02	n.s.
<u>Retail cuts</u>						
Neck (kg)	1.07 \pm 0.02	1.06 \pm 0.02	**	1.28 \pm 0.02	0.86 \pm 0.02	**
Shoulder (kg)	3.76 \pm 0.10	4.25 \pm 0.08	*	4.80 \pm 0.10	3.20 \pm 0.08	**
Chuck (kg)	3.68 \pm 0.09	3.82 \pm 0.07	n.s.	4.24 \pm 0.08	3.26 \pm 0.07	**
Flatrib (kg)	2.43 \pm 0.09	2.92 \pm 0.08	*	3.38 \pm 0.09	1.97 \pm 0.08	**
Prime rib (kg)	1.78 \pm 0.07	2.01 \pm 0.05	n.s.	2.39 \pm 0.07	1.41 \pm 0.06	**
Loin (kg)	2.35 \pm 0.08	2.72 \pm 0.06	*	3.02 \pm 0.08	2.05 \pm 0.07	**
Hindquarters (kg)	7.09 \pm 0.14	7.27 \pm 0.11	n.s.	8.17 \pm 0.14	6.2 \pm 0.12	**

* = Significant (P<0.05)

** = Significant (P<0.01)

n.s. = Not Significant

Table 2. Mean (\pm SE) proximate chemical composition of the *m. longissimus dorsi* from the 11/13th-rib cut of SAMM and Dormer rams and ewes.

Trait	Breed			Sex		
	SAMM	Dormer	Significance	Ram	Ewes	Significance
<u>Number</u>	12	12		12	12	
Moisture	74.09 \pm 0.24	74.33 \pm 0.25	n.s.	74.54 \pm 0.24	73.88 \pm 0.24	n.s.
Protein	22.18 \pm 0.22	21.93 \pm 0.23	n.s.	21.74 \pm 0.22	22.36 \pm 0.22	*
Lipid	3.33 \pm 0.20	3.14 \pm 0.21	n.s.	2.86 \pm 0.21	3.61 \pm 0.21	*
Ash	1.22 \pm 0.01	1.19 \pm 0.01	n.s.	1.17 \pm 0.01	1.24 \pm 0.01	**

* = Significant (P<0.05)

** = Significant (P<0.01)

n.s. = Not Significant

Table 3. Mean (\pm SE) carcass parameters of rams and ewes after adjustment for live weight at slaughter.

Trait	Sex		Significance
	Ram	Ewes	
<u>Number</u>	38	58	
<u>Carcass characteristics</u>			
Carcass weight (kg)	21.20 \pm 0.29	23.74 \pm 0.21	**
Carcass length (cm)	76.91 \pm 0.70	79.17 \pm 0.58	**
Carcass width (cm)	24.84 \pm 0.34	26.41 \pm 0.26	**
Leg circumference 2 (cm)	26.95 \pm 0.46	28.71 \pm 0.35	**
Eye-muscle area (cm ²)	12.11 \pm 0.47	14.84 \pm 0.36	**
Fat depth (mm)	0.69 \pm 0.16	1.87 \pm 0.12	**

* = Significant (P<0.05)

** = Significant (P<0.01)

When expressed as a proportion of live weight and carcass weight, there were some significant differences in carcass component weights, organ weights and retail cut weights between the two sexes (Table 4). The proportions of the different organ weights as percentage of live weight of the rams were generally higher than those from the ewes. The ewes had a significantly (P<0.01) higher proportion of kidney fat than rams. Retail cuts as proportion of carcass weight are shown in Table 4.

Table 4. The effect of sex on carcass yields.

Trait [#]	Sex		Significance
	Ram	Ewes	
<u>Number</u>	38	58	
<u>Carcass characteristics</u>			
Skin (%) ^a	8.52±0.13	8.19±0.12	*
Trotters (%) ^a	2.29±0.04	1.98±0.03	**
<u>Organs</u>			
Kidney (%) ^a	0.29±0.01	0.26±0.01	**
Liver (%) ^a	2.11±0.03	1.69±0.03	**
Lungs (%) ^a	1.55±0.03	1.48±0.03	*
Kidney fat (%) ^a	0.41±0.04	0.55±0.03	**
<u>Retail cuts</u>			
Neck (%) ^b	4.62±0.08	4.50±0.07	*
Shoulder (%) ^b	17.32±0.21	16.59±0.18	**
Chuck (%) ^b	15.35±0.27	17.00±0.24	**
Flatrib (%) ^b	12.07±0.19	10.17±0.17	**
Primerib (%) ^b	8.54±0.16	7.29±0.14	**
Hindquarters (%) ^b	29.25±0.32	32.32±0.28	**

* = Significant (P<0.05) ** = Significant (P<0.01)

^a Percentage of live weight

^b Percentage of cold carcass weight

[#] Only those parameters that differed significantly are shown

After adjustment for live weight, only the moisture (75.35±0.37 and 73.35±0.37% for rams and ewes) and lipid (2.68±0.33 and 3.80±0.33% for rams and ewes) contents differed significantly (P<0.05) between sexes.

As there was no sex x breed interaction for the fatty acid composition of the *m. longissimus dorsi*, the data were tested for sex and breed. There were only a few differences in the fatty acid composition between SAMM and Dormer sheep (pooled sexes) and the rams and ewes (pooled breeds) (Table 5).

Table 5. Fatty acid profile of the *m. longissimus dorsi* from the 11/13th-rib cut of SAMM and Dormer rams and ewes (% of identified fatty acids).

Trait	Breed			Sex		
	SAMM	Dormer	Significance	Ram	Ewes	Significance
Number	12	12		12	12	
C14:0	1.52±0.13	2.26±0.13	**	1.82±0.13	1.96±0.13	ns.
C16:0	22.83±0.94	25.70±0.95	ns.	25.28±0.97	23.25±0.93	ns.
C18:0	23.26±0.85	23.13±0.86	ns.	23.48±0.88	22.91±0.84	ns.
C20:0	0.032±0.03	0.16±0.03	**	0.07±0.03	0.12±0.03	ns.
C22:0	0.012±0.018	0.024±0.01	ns.	0.011±0.01	0.025±0.01	ns.
C24:0	0.024±0.01	0.034±0.01	ns.	0.009±0.02	0.049±0.01	ns.
SFA ¹	47.68±1.20	51.31±1.21	*	50.67±1.23	48.32±1.17	ns.
C16:1n7	1.40±0.10	1.35±0.10	ns.	1.42±0.11	1.32±0.10	ns.
C18:1n9	36.47±0.98	32.88±0.98	*	34.53±1.00	34.82±0.96	ns.
C20:1n9	0.017±0.01	0.049±0.01	ns.	0.017±0.01	0.049±0.01	ns.
C24:1n9	0.035±0.01	0.022±0.01	ns.	0.018±0.01	0.038±0.01	ns.
MUFA ²	37.92±0.90	35.03±0.92	*	36.32±0.92	36.63±0.90	ns.
C18:2n6	5.11±0.39	4.07±0.40	ns.	4.69±0.04	4.50±0.39	ns.
C18:3n6	0.45±0.13	0.18±0.14	ns.	0.15±0.14	0.47±0.13	ns.
C18:3n3	1.93±0.21	1.41±0.21	ns.	2.00±0.21	1.34±0.21	*
C20:2n6	0.16±0.03	0.055±0.03	**	0.13±0.03	0.089±0.0	ns.
C20:3n6	1.36±0.34	1.69±0.35	ns.	1.82±0.35	1.24±0.34	ns.
C20:4n6	1.11±0.08	0.92±0.08	ns.	1.02±0.08	1.01±0.08	ns.
C20:3n3	0.29±0.06	0.12±0.06	ns.	0.13±0.06	0.28±0.06	ns.
C20:5n3	0.76±0.08	0.57±0.09	ns.	0.66±0.08	0.66±0.09	ns.
C22:2n6	1.36±0.52	1.06±0.53	ns.	0.73±0.52	1.68±0.53	ns.
C22:4n6	0.80±0.17	0.20±0.18	*	0.35±0.17	0.66±0.18	ns.
C22:5n3	0.68±0.07	0.54±0.07	ns.	0.55±0.07	0.67±0.07	ns.
C22:6n3	0.37±0.07	0.24±0.07	ns.	0.22±0.07	0.39±0.07	ns.
PUFA ³	14.40±1.28	12.75±1.31	ns.	13.22±1.28	13.92±1.31	ns.
PUFA:SFA ⁴	61.18±1.40	58.73±1.44	ns.	59.39±1.41	60.53±1.44	ns.
DFA ⁵	0.32±0.04	0.26±0.04	ns.	0.27±0.04	0.31±0.04	ns.
(C:18:0+C18:1): C16:0	2.92±0.28	2.28±0.28	ns.	2.36±0.28	2.85±0.28	ns.

* = Significant (P<0.05)

** = Significant (P<0.01)

ns. Not Significant

¹ SFA = Saturated fatty acids² MUFA = Mono-unsaturated fatty acids³ PUFA = Polyunsaturated fatty acids⁴ PUFA: SFA = Polyunsaturated fatty acids to saturated fatty acids ratio⁵ DFA = Desirable fatty acids

The two most prominent saturated fatty acids (SFA) were palmitic acid (C16:0) and stearic acid (C18:0). There were significant differences in myristic acid (C14:0) (P<0.01), arachidic acid (C20:0) (P<0.01) and SFA (P<0.05) between the breeds. Oleic acid (C18:n9) was the most prominent mono-unsaturated fatty acid (MUFA), whilst linoleic acid (C18:2n6) was the most prominent polyunsaturated fatty acid (PUFA).

DISCUSSION

The higher live weight of the rams at slaughter could be attributed to a difference in growth rate and mature size between ewes and rams (Kirton *et al.*, 1995). The higher carcass weight of the rams was a direct result of their higher live weight. Stomach content and skin weight can affect dressing percentage when the live weights are recorded (Kirton *et al.*, 1995). The heavier skin weights of the SAMM sheep could also cause their dressing percentage to be significantly lower (Table 1). The heavier skins of the SAMM sheep could be attributed to the fact that all the sheep were not shorn on the same date. The Dormers had shorter wool and thus a lower skin weight.

All the carcass component weights, organ weights, retail cut weights and eye-muscle areas were generally higher in rams than in ewes. These differences were most probably associated with the higher slaughter weight of the rams. The longer carcasses and hind leg length with the narrower carcasses of the SAMM are an indication that the build of SAMM sheep is more ranky than that of Dormers.

According to Lawrie (1998) an early maturing sheep breed tends to gain fat readily, which could be why the Dormers had more kidney fat and a greater fat depth than SAMM sheep at the same age. The heavier neck retail cut of the SAMM sheep could be associated with the heavier heads of the breed. The neck area is the area where the growth wave starts during development. The SAMM breed is late maturing which could be a reason why the neck and heads from SAMM sheep were heavier at the same age. The loin area is the last region of an animal to develop (Lawrie, 1998), which could possibly explain why the loin retail cut and eye-muscle area from Dormers were heavier and bigger than those from the SAMM sheep (Table 1).

The greater carcass length, width and leg circumference of the ewes could be associated with their heavier carcass weight, after adjustment for live weight. Teixeira *et al.* (1996) state that ewes are fatter than rams at the same carcass weight. The same was found in this study, ewes having a significantly higher percentage of kidney fat, a higher percentage of fat in the *longissimus dorsi* muscle (proximate analysis) and a thicker back fat depth than rams. The meat from rams contained a higher percentage of moisture in the *longissimus dorsi* muscle than that of ewes. This agrees with the findings of Kemp *et al.* (1976).

In the growth and development of animals, rams tend to develop more in the neck and head area than ewes (Jeremiah *et al.*, 1997), which could explain why the proportion of the neck retail cut from rams was higher than ewes. Fahmy *et al.* (1999) found ewes to be more developed in the hindquarters than rams; similar results were found in this investigation. Eye-muscle area is an indication of muscle content in the whole carcass and a significant predictor of muscle in the leg (Hopkins *et al.*, 1992). The phenomenon of heavier forequarters in rams and heavier hindquarters

in ewes is typical of sexual dimorphism, as expected at their age of slaughter (Jeremiah *et al.*, 1997).

It is generally accepted that plasma cholesterol concentration in humans are influenced by the fatty acid composition of dietary lipid (Grundy & Denke, 1990). High dietary levels of SFA increase plasma cholesterol concentrations compared with high levels of MUFA (Grundy & Denke, 1990). With the significantly higher SFA value of the SAMM sheep and higher MUFA value of the Dormer sheep, meat from Dormer sheep could be regarded as healthier from a human prospective than that from SAMM meat.

CONCLUSION

The higher retail cut weights of the Dormer sheep and higher skin, head and trotter weights in SAMM sheep are important observations, since the highest prices are obtained from the meat of the sheep and not the trotters and heads. In accordance with the production objectives of the breeds: SAMM a dual-purpose breed, suitable for the commercial production of meat and wool and the Dormer a specialist sire breed for terminal crossbreeding.

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REFERENCE

- ALASA, 1995. Association of Official Analytical Chemists International, Official methods of analysis of AOAC International, 16th edition, Method 4.5.01 (920.39), AOAC International, Maryland, USA.
- Enright, W.J., Quirke, J.F., Gluckman, P.D., Breier, B.H., Kennedy, L.G., Hart, I.C., Roche, J.F., Coert, A. & Allen, P., 1990. Effects of long-term administration of pituitary-derived bovine growth hormone and estradiol on growth in steer. *J. Anim. Sci.* 68, 2345-2352.
- Fahmy, M.H., Garipey, C. & Fortin, J., 1999. Carcass quality of crossbred lambs expressing the callipyge phenotype born to Romanov purebred and crossbred ewes. *Anim. Sci.* 69, 525- 533.
- Gilmour, A.R., Luff, A.F., Fogarty, N.M. & Banks, R., 1994. Genetic parameters for ultrasonic fat depth and eye muscle measurements in live Poll Dorset sheep. *Aust. J. Agric. Res.* 45, 1281-1291.

- Gilmour, A.R., Cullis, J.J., Welham, S.J. & Thompson, R., 1999. ASREML–Reference manual. NSW Agriculture Biometric Bulletin No. 3. NSW Agriculture Institute, Forest Road, Orange 2800, NSW, Australia.
- Grundy, S.M. & Denke, M.A., 1990. Dietary influences on serum lipids. *J. Lipid. Res.* 31, 1149-1172.
- Hoffman, L.C., 2000. The yield and carcass chemical composition of impala (*Aepyceros melampus*), a Southern African antelope species. *J. Sci. Food. Agric.* 80, 752-756.
- Hopkins, D.L., Gilbert, K.D., Pirlot, K.L. & Robertrs, A.H.K., 1992. Elliottdale and crossbred lambs: growth rate, wool production, fat depth, saleable meat yield, carcass composition and muscle content of selected cuts. *Aust. J. Agric. Res.* 32, 429-434.
- Jeremiah, L.E., Jones, S.D.M., Tong, A.K.W., Robertson, W.M. & Gibson, L.L., 1997. The influence of lamb chronological age, slaughter weight and gender on yield and cutability. *Sheep Goat Res.* 13 (1), 39-46.
- Kemp, J.D., Johnson, A.E., Stewart, D.F., Ely, D.G. & Fox, J.D., 1976. Effect of dietary protein, slaughter weight and sex on carcass composition, organoleptic properties and cooking losses of lamb. *J. Anim. Sci.* 42 (3), 575-583.
- Kirton, A.H., Carter, A.H., Clarke, J.N., Sinclair, D.P., Mercer, G.J.K. & Duganzich, D.M., 1995. A comparison between 15 ram breeds for export lamb production 1. Liveweights, body composition, carcass measurements and composition. *N. Z. Agric. Res* 38, 347-360.
- Lawrie, R.A., 1998. *Lawrie's Meat Science*. Sixth Edition. Woodhead Publishing Limited, Cambridge, England.
- Morrison, W.R. & Smith, M.L., 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. *J. Lipid. Res.* 5: 600-602.
- Neser, F.W.C., Erasmus, G.J. & Van Wyk, J.B., 2000. Genetic studies on the South African Mutton Merino: growth traits. *S. Afr. J. Anim. Sci.* 30 (3), 172-177.
- Oman, J.S., Waldron, D.F., Griffin, D.B. & Savell, J.W., 1999. Effects of breed-type and feeding regimen on goat carcass traits. *J. Anim. Sci.* 77, 3215-3218.
- Purchas, R.W., 1978. Some effects of nutrition and castration on meat production from male Suffolk cross (Border Leicester-Romney cross) lambs. 1. Growth and carcass quality. *N. Z. J. Agric. Res.* 21, 370-376.
- Sañudo, C., Sierra, I., Oletta, J.L., Martin, L., Campo, M.M., Santolaria, P., Wood, J.D. & Nute, G.R., 1998. Influence of weaning on carcass quality, fatty acid composition and meat quality in intensive lamb production systems. *Anim. Sci.* 66, 175-187.

- Stanford, K., Woloschuk, C.M., McClelland, L.A., Jones, S.D.M. & Price, M.A., 1997. Comparison of objective external carcass scores for prediction of lamb carcass quality. *Can. J. Anim. Sci.* 77, 217-223.
- Teixeira, A., Delfa, R. & Treacher, T., 1996. Carcass composition and body fat depots of Galego Bragançano and crossbred lambs by Suffolk and Merino Precoce sire breeds. *Anim. Sci.* 63, 389-394.
- Van der Merwe, C.A., 1976. Genetiese en nie-genetiese faktore wat die produksie en reproduksie eienskappe van die Elsenburg Dormer Skaapkudde beïnvloed. Ph.D. (Agric)-Thesis. University of Stellenbosch.
- Van Wyk, J.B., Erasmus, G.J. & Konstantinov, K.V., 1993. Non-genetic factors influencing early growth traits in the Elsenburg Dormer sheep stud. *J. Anim. Sci.* 23, 67- 71.

Chapter 6

MEASUREMENT OF SUBCUTANEOUS BACKFAT AND *M. LONGISSIMUS DORSI* DEPTH IN LIVE MERINO, SA MUTTON MERINO AND DORMER SHEEP WITH AN ULTRASONIC PROBE

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ABSTRACT

The *longissimus dorsi* muscle depth and backfat depth were measured ultrasonically at the 13th rib 25 and 45 mm from the midline of 52 Merino rams (belonging to two lines divergently selected for ewe multiple rearing ability), 61 Dormer sheep (21 rams and 40 ewes) and 35 South African Mutton Merino (SAMM, 17 rams and 18 ewes). All sheep were scanned 24 hours prior to slaughter with a SZANZO INC. (scano probe 2) scanner using a 3.5 MHz linear probe. Prior to scanning, the animals were shorn to ensure as little wool as possible on the skin surface. All sheep were slaughtered after scanning and the true backfat and eye muscle depths were measured on the carcasses. Overall regression equations over breeds (SAMM and Dormers), sexes and lines (H and L line Merinos) were obtained. Low correlations were found between measurements derived from ultrasound scanning and those measured directly on the carcasses. Higher correlations were achieved in older and fatter animals.

Key words: Fat depth, *Longissimus* muscle, sheep, ultrasound

INTRODUCTION

There is evidence that consumers are demanding leaner cuts of red meat (Gilmour *et al.*, 1994). If sheep meat is to hold or extend its market share, the fat content has to be reduced. The development of boneless lamb cuts which are low in fat and high in lean meat is aimed at meeting these consumer demands (Gilmour *et al.*, 1994). Live weight and fat depth variation play a major role with regard to marketability of slaughter lambs. The development of carcass merit pricing systems requires the use of objective technologies for assessing carcass composition or lean distribution. Accurate subjective evaluation of yield grade could possibly identify differences in carcass composition and could conceivably be the basis for lamb carcass pricing. Even using the

most experienced evaluators, this subjective assessment is at best a marginal predictor of lamb carcass composition (Berg *et al.*, 1997).

Many experiments measuring carcass fat components have shown that most fat components measurements are heritable (Botkin *et al.*, 1969; Wolf *et al.*, 1981; Bennet *et al.*, 1991). Breeding programmes have consequently been proposed as a means of reducing fat content. Ultrasound has been used to estimate lamb carcass composition in many countries (Stanford *et al.*, 2001). An advantage of ultrasonic technology over other proposed methods is the lower cost of machinery and it is already successfully used in the pig-breeding industry (McEwan *et al.*, 1993). Different ultrasonic technologies to measure fat depth over the *m. longissimus dorsi* at the 12th rib has been used successfully in sheep breeding research programs to alter the carcass composition (Gooden *et al.*, 1980).

Two different types of scanners can be used: a scanner that produces a one-dimensional profile of the tissue, which is ideal for measuring the depth to the fat/muscle interface. The second scanner produces a two-dimensional image to outline the eye-muscle (*m. longissimus dorsi*) area, although the resolution of interface perpendicular to the skin is poor (Gilmour *et al.*, 1994). A very experienced operator is required to take the ultrasonic measurements. This investigation was done to test the suitability of a one-dimensional ultrasound scanner (regularly used on pigs) for predicting subcutaneous backfat and *m. longissimus dorsi* depth on Merino, SA Mutton Merino and Dormer sheep.

MATERIAL AND METHODS

The trial was conducted at Elsenburg experimental farm. Data from 52 Merino rams, 61 Dormer sheep (21 rams and 40 ewes) and 35 South African Mutton Merino (SAMM) (17 rams and 18 ewes) were used in this investigation. The Merino rams were 19 months of age at assessment and the other breeds 18 months. The Merino rams were descended from two selection lines, a high reproductive (H) line and a low reproductive (L) line. Cloete & Scholtz (1998) have described the selection procedure in detail. The Merino rams were maintained in the same flock from birth up to slaughter. The Dormer and SAMM rams were also maintained in the same flock as were the Dormer and SAMM ewes.

All the sheep were scanned with a SZANZO INC. (scano probe 2) scanner using a 3.5 MHz linear probe to produce a one-dimensional profile of the tissue. Prior to scanning the animals were shorn to ensure as little wool as possible on the skin surface. The animals were scanned and weighed 24 hours prior to slaughter.

Vegetable oil was used as a coupling medium between the probe and the skin (Hopkins *et al.*, 1996). The probe was placed onto the body surface over the *m. longissimus dorsi* (eye muscle) at the C site (25 mm from the midline at the 13th rib) and at the GR site (45 mm from the midline at the 13th rib) for measuring the subcutaneous fat and *m. longissimus dorsi* depths (Gilmour *et al.*, 1994).

All the sheep were slaughtered after scanning. Recordings on the carcasses included backfat depth, skin thickness and eye-muscle depth. After 48 hours in the cooler the carcasses were partitioned and the backfat depth and eye muscle depths were measured 25 mm and 45 mm from the midline at the 13th rib (the same site as scanned). The thickness of the skin was also measured at the same site. This allowed for the correction of skin thickness from the combined skin and backfat measurements obtained from the scanner (Gilmour *et al.*, 1994).

The measurements taken on the carcasses were taken as true measurements and regressed on scanned values. This process allowed the calibration of the recordings obtained indirectly with the true measurements on the carcass (Cloete & Haughey, 1990). Overall regression equations over breeds (SAMM and Dormers), sexes and lines (H and L line Merinos) were obtained using ASREML (Gilmour *et al.*, 1999). The reduction in residual mean squares due to grouping according to breed, sex and line was used to test whether the slopes and/or y-intercepts of individual breed/line-specific regressions differed significantly. To identify the most appropriate functions to describe the changes, F-values from these analyses were primarily used.

RESULTS

The data of the SAMM and Dormer sheep were pooled, whilst the data of the Merino rams (H and L line) were pooled and analysed separately. Means, standard deviations and ranges of backfat (25 and 45 mm from the midline at the 13th rib) and eye-muscle depth (25 and 45 mm from the midline at the 13th rib) after correction for skin thickness of Merinos rams are given in Table 1 and those of SAMM and Dormer sheep in Table 2.

The reduction in residual mean squares due to grouping according to breed and sex in Dormer and SAMM sheep and line in the case of Merino was used to test whether the y-intercepts and/or slopes of individual breed/sex/line-specific regressions differed ($P < 0.05$) (Table 3). It is noteworthy to see that the overall slopes in Table 3 were generally not significant.

Scatter-plots of the relationship between direct measurements on the carcass and the scanning values are presented. Results for the Merino rams are depicted in Figures 1 to 4. Where the regressions differed ($P < 0.05$) between lines, the line-specific regressions are presented, otherwise only an overall regression line across lines is presented. There was a difference in the

slope of the regression lines for backfat depth (measured 45mm from the midline) of the two Merino lines (Figure 2).

Table 1. Mean (\pm SE) and ranges of backfat and eye-muscle depth of Merino rams obtained from the carcass measurements and ultrasonic estimates

Place of measurement	Method			
	Carcass measurements		Ultrasonic measurements	
	Mean (\pm SE)	Range	Mean (\pm SE)	Range
<u>Backfat 25 mm off midline (mm)</u>				
H Line (n=41)	0.54 \pm 0.06	0.0 – 3.3	2.25 \pm 0.71	1.0 – 4.0
L Line (n=10)	0.29 \pm 0.04	0.0 – 0.9	2.05 \pm 0.96	1.0 – 4.0
<u>Backfat 45 mm off midline (mm)</u>				
H Line	0.44 \pm 0.05	0.2 – 2.0	2.62 \pm 0.64	1.25 – 4
L Line	0.27 \pm 0.03	0.0 – 0.8	2.55 \pm 0.70	1.50 - 4
<u>Eye muscle depth 25 mm off midline (mm)</u>				
H Line	23.52 \pm 3.43	16.7 – 31.7	22.78 \pm 2.56	16.5 – 27.0
L Line	24.10 \pm 4.02	17.7 – 31.2	22.45 \pm 3.19	19.0 – 28.5
<u>Eye muscle depth 45 mm off midline (mm)</u>				
H Line	19.74 \pm 3.50	11.8 – 27.4	33.20 \pm 3.34	16.3 – 37.8
L Line	17.83 \pm 3.70	11.8 – 23.5	32.15 \pm 2.86	28.3 – 38.5

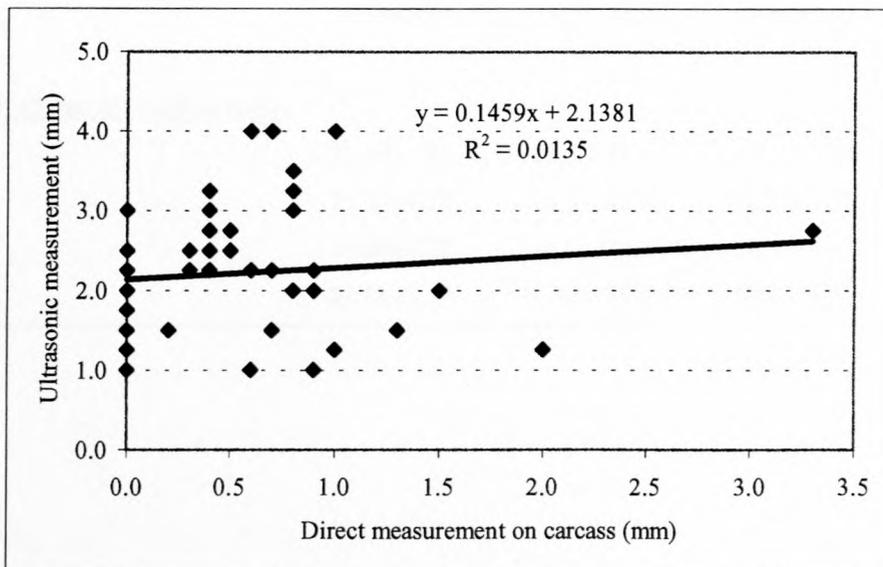


Figure 1. Scatter-plot depicting the relationship between direct backfat measurements 25mm from the midline at the 13th rib and the ultrasonic scanning values of Merino rams.

Table 2. Mean (\pm SE) and ranges of backfat and eye-muscle depth of Dormer (rams and ewes) and SAMM (rams and ewes) obtained from the carcass measurements and ultrasonic estimates (corrected for skin thickness).

Place of measurement	Method			
	Carcass measurements		Ultrasonic measurements	
	Mean (\pm SE)	Range	Mean (\pm SE)	Range
<u>Backfat 25 mm off midline (mm)</u>				
Dormer rams (n=21)	1.77 \pm 0.06	0.6 – 3.0	4.19 \pm 0.93	3.0 – 6.0
Dormer ewes (n=40)	1.46 \pm 0.08	0.4 – 3.5	4.54 \pm 0.82	3.0 – 6.0
SAMM rams (n=17)	1.22 \pm 0.05	0.6 – 1.9	4.18 \pm 1.07	3.0 – 6.0
SAMM ewes (n=18)	1.67 \pm 0.49	0.3 – 1.9	4.00 \pm 0.77	3.0 – 5.0
<u>Backfat 45 mm off midline (mm)</u>				
Dormer rams	1.89 \pm 0.07	1.1 – 3.4	4.19 \pm 1.17	2.0 – 6.0
Dormer ewes	1.50 \pm 0.09	0.4 – 3.9	4.67 \pm 0.74	3.0 – 6.0
SAMM rams	1.26 \pm 0.04	0.7 – 2.0	4.18 \pm 0.19	3.0 – 6.0
SAMM ewes	1.11 \pm 0.05	0.5 – 2.0	4.33 \pm 0.77	3.0 – 6.0
<u>Eye-muscle depth 25 mm off midline (mm)</u>				
Dormer rams	32.88 \pm 5.87	16.0 – 41.4	29.71 \pm 2.10	26.0 – 33.0
Dormer ewes	27.88 \pm 3.18	18.3 – 35.1	29.26 \pm 1.50	25.0 – 32.0
SAMM rams	27.50 \pm 2.88	24.8 – 35.3	28.41 \pm 2.74	22.0 – 32.0
SAMM ewes	27.53 \pm 2.64	21.5 – 31.2	29.17 \pm 1.82	27.0 – 32.0
<u>Eye-muscle depth 45 mm off midline (mm)</u>				
Dormer rams	32.16 \pm 4.65	23.5 – 41.1	18.33 \pm 2.54	15.0 – 16.0
Dormer ewes	25.39 \pm 5.52	14.3 – 48.2	18.59 \pm 1.45	15.0 – 22.0
SAMM rams	28.68 \pm 6.32	14.0 – 14.5	18.29 \pm 3.04	15.0 – 28.0
SAMM ewes	22.18 \pm 3.23	17.3 – 29.2	18.67 \pm 1.64	16.0 – 22.0

Table 3. The F-value due to grouping according to breed (SAMM and Dormer, Trial 1), sex and line (H and L line in Merinos, Trial 2) to see whether the y-intercepts of individual breed/line-specific regressions differed and the slopes of individual breed/line-specific regressions differed significantly ($P < 0.05$).

Parameter	Fat depth 25		Fat depth 45		Eye muscle 25		Eye muscle 45	
	F	P	F	P	F	P	F	P
<u>Trial 1:</u>								
Intercepts:								
Breed	4.79	*	3.46	ns.	3.14	ns.	0.05	ns.
Sex	7.25	**	12.92	**	0.94	ns.	2.32	ns.
Slopes:								
Overall	1.95	ns.	0.32	ns.	2.91	ns.	1.84	ns.
* Breeds	0.23	ns.	0.21	ns.	3.72	ns.	4.09	*
* Sexes	0.01	ns.	0.00	ns.	4.20	*	0.00	ns.
<u>Trial 2:</u>								
Intercept:								
Line	0.37	ns.	0.00	ns.	0.16	ns.	0.30	ns.
Slopes:								
Overall	0.67	ns.	4.53	*	0.38	ns.	3.35	ns.
* Lines	1.16	ns.	4.08	*	2.08	ns.	1.10	ns.
* $P < 0.05$	** $P < 0.01$	ns. Not significant						

Results of Dormer and SAMM sheep are depicted in Figures 5 to 8. Where the regression lines differed significantly between the breeds (SAMM or Dormer) and sexes (male or female), breed- or sex-specific regression lines are presented, otherwise only one regression line is presented. The slopes of the regression lines derived for eye-muscle depth (25 mm from midline) differed significantly between rams and ewes (pooled across SAMM and Dormer sheep) (Figure 7). There was also a significant difference in the slopes of the regression lines from the eye muscle depth (45 mm from midline) between the SAMM and Dormer sheep (Figure 8).

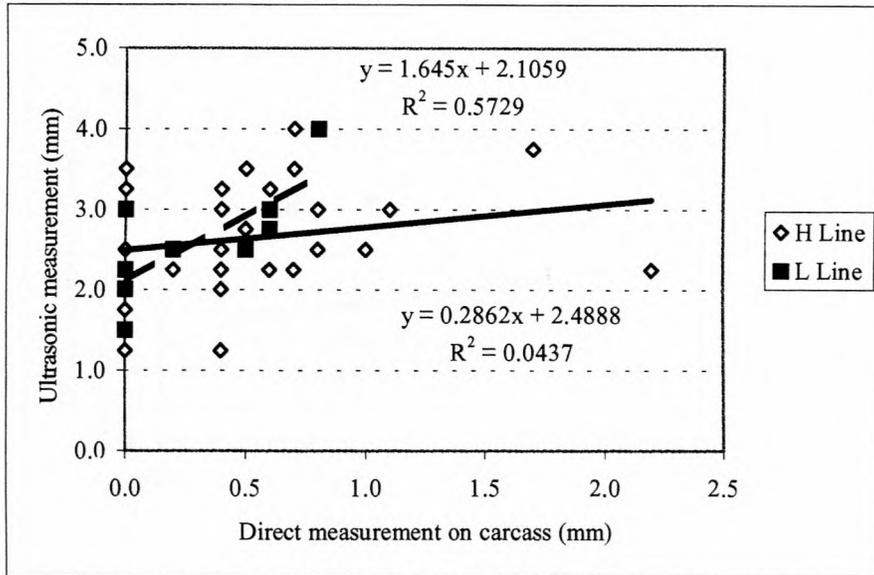


Figure 2. Scatter-plot depicting the relationship between direct backfat measurement 45 mm from the midline at the 13th rib and the ultrasonic scanning values at the same place of Merino rams of the H and L line, with the regression line being $y = 0.2862x + 2.2888$ ($R^2 = 0.0437$) for the H line and $y = 1.645x + 2.1059$ ($R^2 = 0.5729$) for the L line.

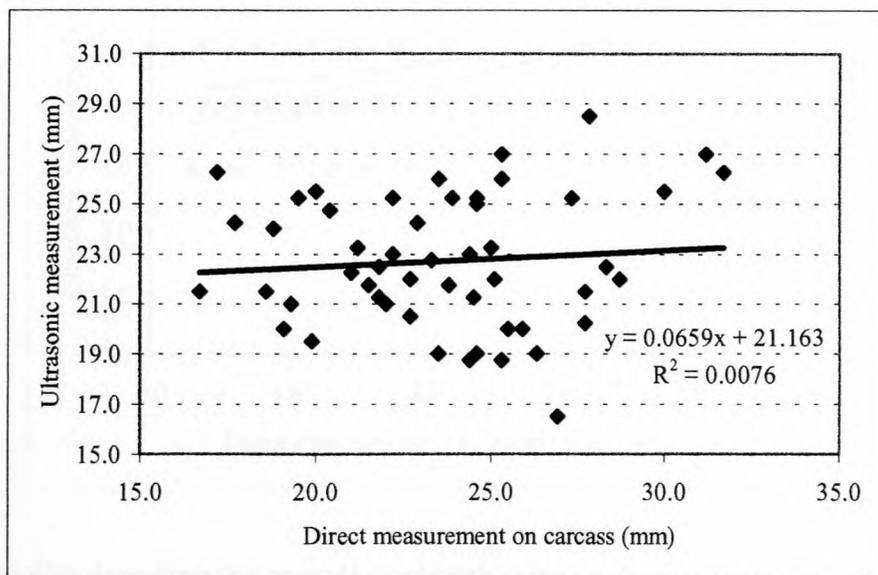


Figure 3. Scatter-plot depicting the relationship between direct eye-muscle depth measured 25 mm from the midline at the 13th rib and the ultrasonic scanning values of Merino rams.

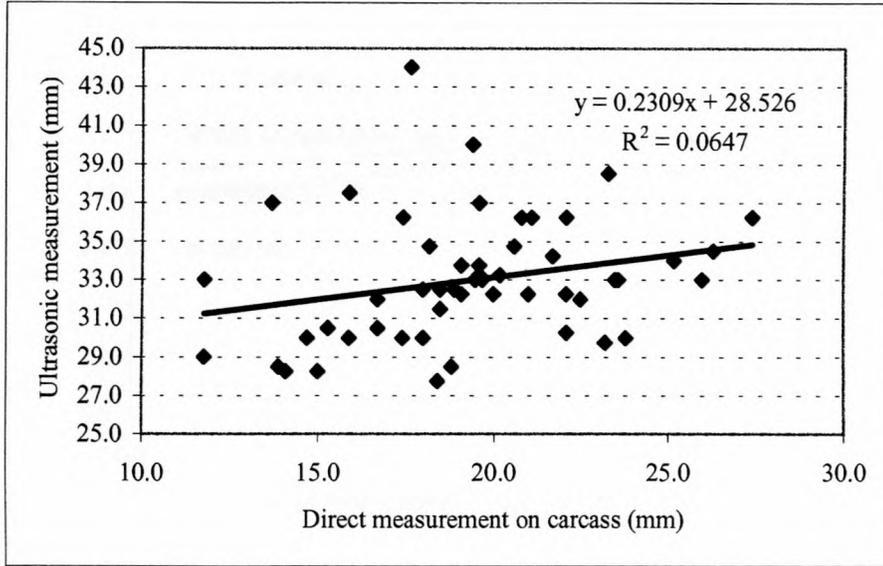


Figure 4. Scatter-plot depicting the overall relationship between direct eye-muscle depth measured 45 mm from the midline at the 13th rib and the ultrasonic scanning values at the same position in Merino rams.

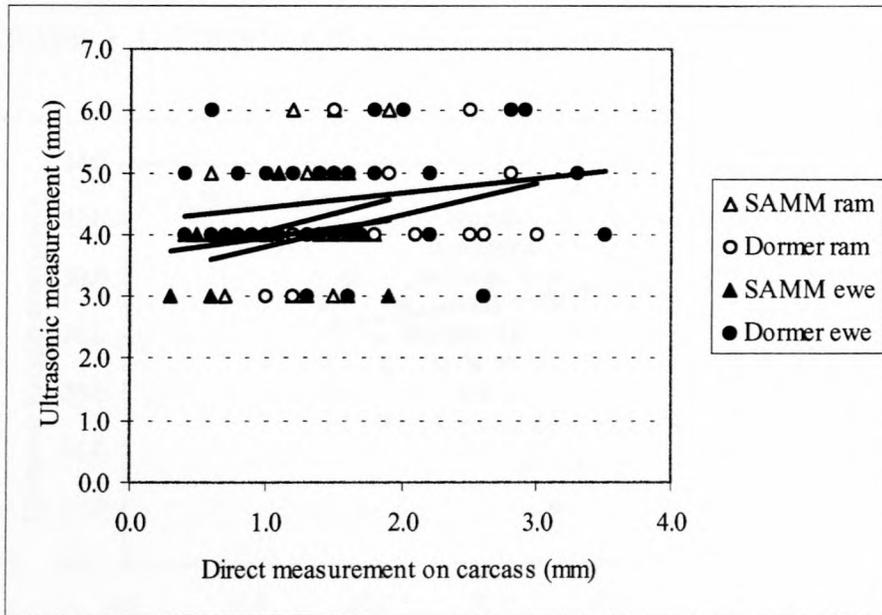


Figure 5. Scatter-plot depicting the overall relationship between direct backfat depth measured 25 mm from the midline at the 13th rib and the ultrasonic scanning values at the same position in SAIM and Dorner sheep, with the regression line for Dorner rams being $y = 0.5128x + 3.2821$ ($R^2 = 0.1224$, $r = 0.35$), for Dorner ewes being $y = 0.2317x + 4.1999$ ($R^2 = 0.0479$), SAIM rams being $y = 0.5566x + 3.4922$ ($R^2 = 0.0416$) and for SAIM ewes being $y = 0.3202x + 3.6264$ ($R^2 = 0.0416$).

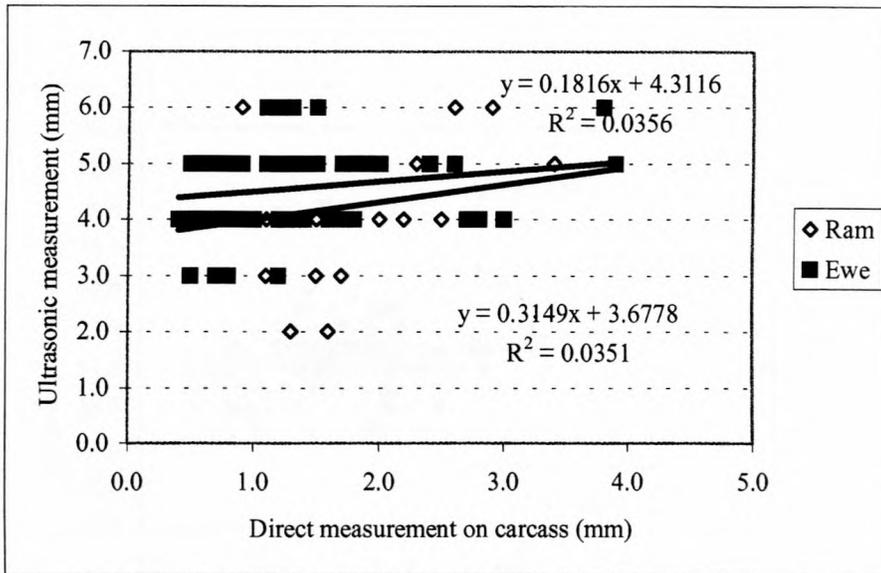


Figure 6. Scatter-plot depicting the overall relationship between direct backfat depth measured 45 mm from the midline at the 13th rib and the ultrasonic scanning values at the same position in SAMM and Dormer sheep, with the regression line being $y = 0.1816x + 4.3116$ ($R^2 = 0.0356$) for the ewes and $y = 0.3149 + 3.6778$ ($R^2 = 0.0351$) for the rams.

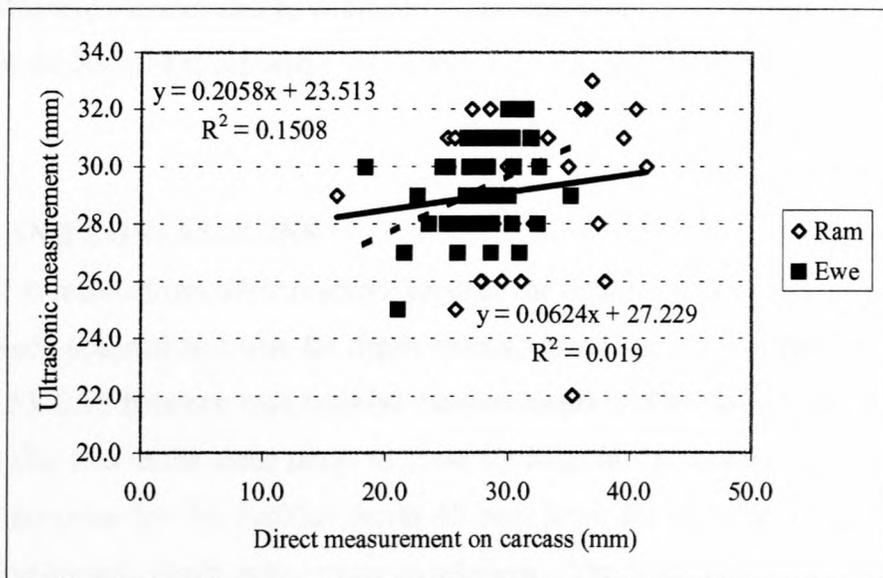


Figure 7. Scatter-plot depicting the sex-specific relationships between direct eye-muscle depth measured 25 mm from the midline at the 13th rib and the ultrasonic scanning values at the same position in SAMM and Dormer sheep, with the overall regression line being $y = 0.2058x + 23.513$ ($R^2 = 0.1508$) for the ewes and $y = 0.0624x + 27.229$ ($R^2 = 0.019$).

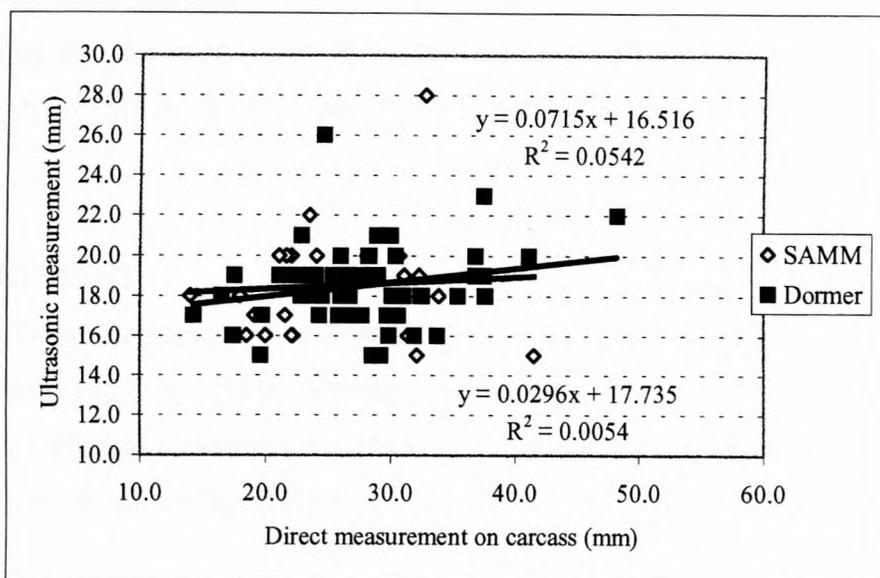


Figure 8. Scatter-plot depicting the breed-specific relationship between direct eye-muscle depth measured 45 mm from the midline at the 13th rib and the ultrasonic scanning values at the same position in SAMP and Dormer sheep, with the overall regression line being $y = 0.0715x + 16.516$ ($R^2 = 0.0542$) for the SAMP sheep and $y = 0.0296x + 17.735$ ($R^2 = 0.0054$) for the Dormer sheep.

DISCUSSION AND CONCLUSIONS

Compared to results from other research reports, the data from this experiment suggest a low correlation between scanned and true fat depth values. Hopkins *et al.* (1996) found correlations ranging from 0.53–0.56 between true backfat measurements and ultrasound measurements. The only correlation that was in the same range to those findings in the present experiment was that of the L line Merino rams for the backfat depth 45 mm from the midline (Figure 2). Even the correlation for eye-muscle depth was comparatively low. The best correlation of 0.39 was found for Dormer and SAMP rams (Figure 7), and even this tended to be lower than the correlation reported by Hopkins *et al.* (1996).

It has to be concluded that the relationships between scanned figures and those obtained on individual carcasses were relatively poor in the present study. In the literature it is stated that the experience of the operator would have a marked influence on the results (Stanford *et al.*, 2001). The operator in the present investigation has had a lot of experience in the scanning of pigs, but it

was his first attempt at the scanning of sheep. There is also evidence that better correlations could have been expected in the scanning of older, fatter animals (Hopkins *et al.*, 1996). Research on ultrasound scanning for the assessment of carcass composition is set to continue, since it is foreseen to play a future role in the selection of particularly dual-purpose and meat sheep in South Africa.

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REFERENCES

- Bennet, G.L., Meyer, H.H. & Kirton, A.H., 1991. Genetic and environmental effects on carcass characteristics of Southdown x Romney lambs: 1. Growth rate, sex, and rearing effects. *J. Anim. Sci.* 69, 1856-1863.
- Berg, E.P., Neary, M.K., Forrest, J.C. & Thomas, D.L., 1997. Evaluation of electronic technology to assess lamb carcass composition. *J. Anim. Sci.* 75, 2433-2440.
- Botkin, M.P., Field, R.A., Riley, M.L., Nolan, J.C. & Roehrkaase, G.P., 1969. Heritability of carcass traits in lambs. *J. Anim. Sci.* 29, 251-255.
- Cloete, S.W.P. & Haughey, K.G., 1990. Radiographic pelvimetry for the estimation of pelvic dimensions in Merino, Dormer and SA Mutton Merino ewes. *J. S. Afr. vet. Assoc.* 61 (2), 55-58.
- Cloete, S.W.P. & Scholtz, A.J., 1998. Lamb survival in relation to lambing and neonatal behavior in medium wool Merino lines divergently selected for multiple rearing ability. *Aust. J. Exp. Agric.* 38, 801-811.
- Gilmour, A.R., Luff, A.F., Fogarty, N.M. & Banks, R., 1994. Genetic parameters for ultrasound fat depth eye muscle measurements in live Poll Dorset sheep. *Aust. J. Agric. Res.* 45, 1281-1291.
- Gilmour, A.R., Cullis, J.J., Welham, S.J. & Thompson, R., 1999. ASREML—Reference manual. NSW Agriculture Biometric Bulletin No. 3. NSW Agriculture Institute, Forest Road, Orange 2800, NSW, Australia .

- Gooden, J.M., Beach, A.D. & Purchas, R.W., 1980. Measurements of subcutaneous backfat depth in live lambs with an ultrasonic probe. *N. Z. J. Agric. Res.* 23, 161-165.
- Hopkins, D.L., Hall, D.G. & Luff, A.F., 1996. Lamb carcass characteristics. *Aus. J. Exp. Agric.* 36, 37-45.
- McEwan, J.C., Clarke, J.N., Hickey, S.M. & Knowler, K.J., 1993. Heritability of ultrasonic fat and muscle depths in Romney sheep. *Proc. N. Z. Soc. Anim. Prod.* 53, 347-350.
- Stanford, K., Bailey, D.R.C., Jones, S.D.M., Price, M.A. & Kemp, R.A., 2001. Ultrasound measurement of *longissimus* dimensions and backfat in growing lambs: effects of age, weight and sex. *Small Rum. Res.* 42, 191-197.
- Wolf, B.T., Smith, C., King, J.W.B. & Nicholson, D., 1981. Genetic parameters of growth and carcass composition in crossbred lambs. *Anim. Prod.* 32, 1-7.

Chapter 7

GENERAL CONCLUSIONS

Experiment 1 and 2: The effect of divergent selection for an increased reproduction rate on carcass weight, mutton production, meat quality and carcass characteristics of Merino sheep was investigated. Selection for reproduction resulted in higher live and carcass weights of H line animals. The higher loin (study A) and hindquarter (study B) weights of H line animals is an important observation, since the highest-priced meat cuts are found in these regions. Differences in favour of the L line were in comparatively lower-priced carcass components, e.g. the skin (in both studies) and trotters (study A). Compared to the Callipyge (which increases growth rate) and Booroola (which increases twinning) genes, but have a negative influence on fat (Booroola) and toughness of meat (Callipyge), selection for reproduction in South African Merino sheep seemed not to have marked effects on these parameters. Progeny of the H line had tougher meat in one study (see Chapter 3), while a similar tendency was observed in another study (see Chapter 2). Selection for multiple rearing ability in Merino sheep resulted in a tendency towards a higher initial pH and a lower ultimate pH. These results could indicate that the H line animals were less susceptible to stress in the pre-slaughter phase than their L line contemporaries. This contention needs to be studied further.

Experiment 3: The effect of increasing age on mutton production potential of Merino and SAMM ewes was also considered. The SAMM sheep is a late-maturing breed and reached a maximum carcass weight at a later stage than Merino ewes. Merino ewes tended to put on fat earlier than SAMM ewes. Merinos were leaner and did not reach the same carcass fat content as the SAMM. After SAMM ewes reached a maximum carcass weight, there was a clear decrease in dressing percentage with increasing age. The results of this study suggests that mature SAMM ewes are likely to produce a heavier but possibly fatter carcass than Merinos at the same age.

Experiment 4: The effects of breed and sex on the carcass composition, yield of retail cuts, fat depth and chemical composition of meat from SAMM and Dormer sheep were also studied. The higher retail cut weights of Dormer sheep and higher skin, head and trotter weights in SAMM sheep are important. The highest prices were obtained from retail cuts, while components like the skin, trotters and head of the sheep were relatively cheap. The higher relative neck retail cut of rams and bigger hindquarter weight of ewes compared to rams is regarded as the result of sexual dimorphism. The higher percentage of hindquarter for the ewes is also important, since the highest priced meat

cuts are found in these regions. It should, however, be stated that meat from ewes is fatter and less acceptable to the consumer.

Experiment 5: Many experiments measuring carcass fat components have shown that the most, if not all fat components, are partially under genetic control. Breeding programmes have thus been proposed as a means of reducing fat content. The advantage of ultrasonic technology over other proposed methods are the lower cost of machinery, and it has been successfully used in the pig-breeding industry. Ultrasonic procedures for the measurement of fat depth over the *m. longissimus dorsi* at the 12th rib have been successfully used in sheep-breeding research programmes to alter carcass composition. A study was done to test an ultrasound scanner for predicting subcutaneous backfat and *m. longissimus dorsi* depth in Merino, SA Mutton Merino and Dormer sheep. Low correlations between ultrasonic and true measurements were found. It is difficult to explain the low correlation between ultrasonic and true measurements, since better relationships were found in previous studies. Evidence from the literature suggests that higher correlations can be achieved in older, fatter animals. A trained and experienced operator in image interpretation on sheep could also contribute to an increased accuracy of measurements. The operator in this case was experienced in pig ultrasonography, but did not have any experience on sheep.

Finally, this study suggests a number of differences between different lines of Merino sheep that were divergently selected of ewe multiple rearing ability from the same base population. Differences in carcass traits between breeds (Merino vs. SAMM and SAMM vs. Dormer) were described in the other chapters. These results suggest that slaughter parameters in local sheep breeds are at least partially under genetic control. Similar results were obtained elsewhere and successful breeding programmes for carcass lean content have been reported. Such results are scarce in the local literature, indicating the necessity for further research on the slaughter characteristics of local sheep breeds.