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Genetic parameter estimation for meat traits in Merinos

Abstract

The carcass characteristics, meat quality and specific muscle enzyme activity was studied in 342 Merino wether hoggets representing 7 bloodlines comprising 2 superfine lines, 2 fine wool lines, 2 medium wool lines and 1 broad wool line over 2 years. All animals were supplemented at pasture for 5 weeks before slaughter with high energy pellets. Fat levels in the superfine bloodlines based on total tissue depth over the 12th rib, 110 mm from the midline were much greater than in other lines. This also applied to fat depth measured over the muscle *longissimus thoracis et lumborum* (LL) for one of the superfine bloodlines when adjusted to the same carcass weight. Differences in LL muscle dimensions were minor, although the broad wool bloodline had a lower depth which translated into a smaller cross-sectional area. Significant differences were detected between bloodlines for muscle pH with superfine animals having the highest values for the LL. The differences for the muscle *semitendinosus* were less consistent between bloodlines, but of the bloodlines the broad wool line had the lowest pH levels in both muscles. There were few differences between bloodlines for the meat colour parameters measured on the LL. In the second year, muscle samples were taken to determine the activity of fructose 1,6-bis-phosphatase, lactate dehydrogenase (LDH), isocitrate dehydrogenase (ICDH) and the concentration of myoglobin, indicators of anaerobic and aerobic metabolism. Samples from 50 carcasses were selected from a medium wool and a superfine bloodline (2 × 25) based on LL muscle pH values. Of the enzymes, only ICDH activity was different between the 2 bloodlines, with muscle from the medium wool bloodline having a significantly higher activity than muscle from the superfine bloodline. This indicates a greater aerobic capacity in the muscle of the medium wool bloodline. The significantly lower muscle pH for medium wool bloodline was mirrored by a lower glycolytic capacity expressed as the LDH/ICDH ratio with a correlation of 0.46. Thus in this dataset, a high pH is related to a change in energy metabolism as reflected by the aerobic/anaerobic capacity of the muscle and this may be a reflection of a change in fibre type frequency, but this remains to be validated.

Contents

1 Background - Section

1.1 Background

Until recently there were no published estimates of heritabilities or genetic correlations for Australian Merinos for carcass or meat quality traits. Initial estimates of genetic parameters for these traits and their relationships with wool traits, namely clean fleece weight and fibre diameter, have been derived (see Fogarty *et al.* 2003). Since Merinos are inherently leaner then measurement of fat depth has a high degree of error as reported by Fogarty *et al.* (2003) so a pre-slaughter feeding program appears necessary. This will also help to ensure that the muscle pH values are not inflated by the interaction of low glycogen and pre-slaughter stress.

For the ongoing development of genetic evaluation programs like SGA, improved precision of these estimates, as well as expansion of the genetic parameter estimates to include additional wool quality and reproduction traits, is needed. There is growing interest by some Merino breeders in improving the genetic merit of their flocks for meat traits, but the impact of this must be established on other measured and visually assessed traits associated with production of quality wool over an animal's lifetime. This project was established to derive the genetic parameters for meat traits in Merino sheep by utilising rams from the QPLU$ project run by NSW DPI at Trangie AR&AS. With the emergence of the Sheep CRC it was decided to replicate a similar project at Katanning, WA under the supervision of DAFWA and running parallel to this SARDI successfully obtained MLA support to collect carcase measures on sheep bred as part of the Selection Demonstration flock (SASDF). To provide more accurate genetic estimates it was decided to conduct a joint analysis of the data sets and the results of this are presented here.

Previous work has shown that the Merino tends to produce meat with a higher pH, which has implications for colour, keeping quality and sometimes tenderness. This higher pH has recently been observed in the Sheep Meat Eating Quality project (see Hopkins *et al.* 2005). From preliminary work it was also identified that within Merinos there are differences between strains with broad wool strains having a higher meat pH. Variation even appeared to exist across the finer wool Merinos, but this required validation. The second purpose of this project was to clarify these findings by measuring muscle pH on weaner wethers bred by NSW DPI at Condobolin AR&AS. These sheep represented a number of different Merino strains.

2 Project Objectives

2.1 Project Objectives

1. Enhanced precision of genetic parameters for meat quality and carcass traits, for incorporation into genetic evaluation systems used by Merino ram breeders by 31 December 2006.
2. Demonstration of the responses in carcass and meat quality traits and meat value to selection on a range of Merino wool breeding objectives in a range of Merino strains by 31 December 2006.
3. Determination of the effect of Merino strain on muscle pH with a decision as to whether examination of the keeping quality is required by 31 December 2003.

3 Methodology

3.1 Methodology – Objectives 1 & 2

3.1.1 Flock structure

The data were collected on 5870 Merino hogget rams that were slaughtered at approximately 18 months of age. The rams were the progeny of 543 sires and 4284 dams and were born over several years in 3 research resource flocks (Table 1). The average number of progeny per sire was 10.8 (range 1 – 56) and average number of progeny per dam was 1.37. The 3 flocks (QPLU$, SASDF and WA) are representative of the major bloodlines and strains in the Australian Merino population and have been described in detail by Safari et al (2007a). The QPLU$ flock is located at Trangie in central western NSW and was established to demonstrate simultaneous improvement in wool weight and reduction in fibre diameter using a range of indexes in fine, medium and broad wool strains (Taylor and Atkins 1997)). The WA flock is located at Katanning WA and was established to examine genetic variation in wool traits (Lewer *et al.* 1992). The SASDF flock is located at Turretfield SA and was established to demonstrate outcomes from alternative breeding strategies, technology transfer and generate diverse lines (Ponzoni *et al.* 1999).

This project capitalised on a research program already under way with the QPLU$ Merino selection lines run by NSW DPI at Trangie Agricultural Research and Advisory Station and funded initially by AWI Pty Ltd. The QPLU$ flock is described in Appendix 1. There are linkages between the QPLU$ flock and other flocks, such as the South Australian Selection Demonstration Flock (Turretfield flock).

For the QPLU$ flock each year ~60-70 Merino sires (8 sires per selection line) were single sire mated to Merino ewes within each of the 9 selection lines across Fine, Medium and Broad wool types of Merino. The scope of the work reported here was to collect data on male progeny born in 2001–2004, but data from male progeny born in 1997 and 1998 have also been included in the analysis to increase the database and the reliability of the estimates. The management and results for the progeny born in 1997 and 1998 have been reported previously (Safari *et al.* 2001; Fogarty *et al.* 2003) and will not be outlined here.

Table 1. Number of sires and rams slaughtered by year of birth in QPLU$, WA and SASDF flocks

Year	QPLU$		WA		SASDF		Total	
	Sires	Rams	Sires	Rams	Sires	Rams	Sires	Rams
1997		678						678
1998		370						370
2000				370				370
2001		484		466				950
2002		503		380		403		1286
2003		509		287		228		1024
2004		411		395		386		1192
Total		2955		1898		1017		5870

3.1.2 Management

Lambs were identified to their sire and dam at lambing and birth type recorded at each site. QPLU$ lambs were weaned at 2.5 months and run separately in gender groups. The QPLU$ animals were first shorn at 9 months of age with the traits recorded at shearing outlined in Table 2. At 15 months of age all QPLU$ animals were shorn for the second time.

Table 2. Objective fleece traits recorded on all progeny

	Males		Females		
	9M	15M	15M	2-6YO	Comments
Greasy fleece weight	✔	✔	✔	✔	
Yield	✔	✔	✔	✔	
Clean fleece weight	✔	✔	✔	✔	
Average fibre diameter	✔	✔	✔	✔	
SD fibre diameter	✔	✔	✔	✔	
CV fibre diameter	✔	✔	✔	✔	
Fibre curvature	✔	✔	✔	✔	1996 Drop on

The rams at each site were ultrasound scanned by industry accredited operators to obtain subcutaneous fat depth (FATUS) and eye muscle depth (EMDUS, 45 mm from the midline over the 12th rib) on live animals. The QPLU$ rams were scanned at approximately 10 months of age and those in the other flocks at approximately 14 months of age. This meant that the QPLU$ rams were lighter at scanning and had lower FATUS and EMDUS than rams in the other flocks (Table 2). Scanning data were not available for the QPLU$ rams born in 1997 and 1998.

Table 3. Means (s.d.) and numbers of rams measured for various traits in QPLU$, WA and SASDF flocks

	QPLU$		WA		SASDF	
	n	Mean (s.d.)	n	Mean (s.d.)	n	Mean (s.d.)
Fat depth ultrasound, FATUS (mm)	1845	1.3 (0.5)	1845	2.4 (0.9)	1016	2.7 (0.9)
Muscle depth ultrasound, EMDUS (mm)	1845	21.0 (3.3)	1845	25.4 (2.7)	1016	26.6 (2.4)
Hot carcass weight, HCWT (kg)	2806	26.6 (4.9)	1868	23.6 (3.2)	930	25.2 (4.1)
Dressing percentage, DP (%)	2746	39.5 (3.3)	1474	38.4 (4.4)	927	39.6 (2.5)
Carcass fat depth GR site, FATGR (mm)	2773	8.6 (3.8)	1850	4.7 (3.8)	606	3.7 (2.3)
Carcass fat depth C site, FATC (mm)	2616	2.4 (1.3)	1849	2.1 (1.2)	776	1.4 (0.7)
Carcass eye muscle depth, EMD (mm)	2878	29.1 (3.8)	1858	28.5 (3.6)	1015	27.9 (4.0)
Carcass eye muscle width, EMW (mm)	2878	63.9 (5.4)	1858	63.7 (5.1)	1015	63.7 (5.4)
Carcass eye muscle area, EMA (cm^2)	2878	18.7 (3.4)	1858	18.2 (2.9)	1015	17.9 (3.5)
Meat colour *L**	2683	33.9 (3.2)	1409	35.2 (3.7)	1015	32.1 (2.4)
Meat colour *a**	2658	19.3 (3.2)	1408	20.9 (4.1)	1014	16.1 (2.0)
Meat colour *b**	2652	8.9 (1.9)	1410	9.7 (2.5)	631	4.3 (1.5)
Meat pH	2825	5.98 (0.33)	1859	6.14 (0.33)	1016	6.10 (0.32)
Weaning weight, WWT (kg)	2918	21.1 (4.8)	1868	28.4 (5.6)	1016	28.3 (5.8)
Shearing weight, ShWT (kg)	2878	59.2 (9.6)	1839	55.5 (9.1)	1011	64.6 (8.5)
Scanning weight, ScWT (kg)	1871	41.8 (8.1)	1844	59.1 (6.3)	1016	63.1 (8.2)
Slaughter weight, SWT (kg)	2857	67.4 (10.5)	1474	61.0 (6.6)	927	63.4 (8.0)
Weaning age, WAGE (days)	2918	76 (9)	1868	95 (10)	1016	90 (12)
Slaughter age, SAGE (days)	2877	568 (16)	1868	543 (49)	1016	538 (13)
Greasy fleece weight, GFW (kg)	2891	6.07 (1.95)	1854	4.33 (0.72)	1013	6.35 (0.91)
Clean fleece weight, CFW (kg)	2891	4.27 (1.25)	1841	2.96 (0.49)	1013	4.39 (069)
Average fibre diameter, FD (μm)	2917	20.8 (2.7)	1836	18.9 (1.6)	1016	19.2 (1.6)
Clean yield, YLD (%)	2889	71.0 (6.3)	1850	68.6 (5.4)	1016	69.2 (5.6)
Coefficient of variation of FD, CVFD (%)	2917	21.9 (3.0)	1836	23.9 (3.0)	1016	22.2 (2.9)
Standard deviation of FD, SDFD (μm)	2917	4.56 (0.89)	1836	4.51 (0.67)	1016	4.27 (0.67)
Staple strength, SS (N/ktex)	-	-	1845	25.2 (9.4)	1016	30.9 (10.1)
Fibre curvature, FCURV (°)	-	-	1830	85.4 (11.0)	1016	88.6 (10.1)

QPLU$ hogget rams were allocated to 2 slaughter groups in November of each year, balanced for sire. Rams were introduced to grain and then supplementary fed at pasture (a mixture of nature grasses and lucerne) for 5 weeks with pellets at 1kg/head.day every second day. In 2002 due to drought the animals were fed grain from July until pellet feeding commenced in December. The pellets were made on site at Trangie and consisted of 30% lucerne, 20% lupins, 30% wheat and 20% oats with bentonite, salt and lime added. These pellets had an average crude protein level of 19.7%, a ME of 12.1 MJ/kg DM and a digestibility of 77.4%.

3.1.3 Slaughter procedures and measurements

Across sites the rams were slaughtered at approximately 18 months of age in commercial abattoirs. The rams were transported to the abattoirs and kept in lairage overnight and slaughtered the next day. The carcasses were subject to standard AUS-MEAT trim, which involved removal of kidneys and internal fats. Hot carcass weight (HCWT) was recorded and fat depth at the GR site (FATGR, soft tissue depth at the 12th rib 110 mm from the midline) was measured using a GR knife on the hot carcass. Dressing percentage (DP) was calculated as the ratio of HCWT to fasted liveweight (SWT) prior to transport to the abattoirs. The carcasses were held in chillers at <5°C and 24h after slaughter they were cut between the 12th and 13th rib and eye muscle (*m. longissimus thoracis et lumborum*) depth (EMD), width (EMW) and fat depth over the eye muscle (FATC) were measured. The cross-sectional area of the eye muscle (EMA) was estimated as 80% of the product of EMD and EMW. Meat colour was measured on the cut surface of the eye muscle after at least 30 minutes exposure to the air using a Minolta Chromameter set on the *L**, *a**, *b** system (where *L** measures relative lightness, *a** relative redness, and *b** relative yellowness), except for the 2003 born rams in WA which only had about 10 minutes exposure. The pH of the eye muscle was also measured at this time. Carcasses from the QPLU$ (2002-2004 birth years), WA and SASDF(?) flocks were subject to electrical stimulation as part of the commercial slaughtering process. This allows the muscle to reach ultimate pH sooner to improve meat quality. For SASDF rams born in 200X-Y the abattoirs did not have electrical stimulation facilities and the carcasses were chilled for 48 hours to reach ultimate pH before they were cut and the carcass and meat measurements recorded. For the 2001 QPLU$ carcasses muscle samples were also collected and held for 3 days and measured again for pH. The pH at 24 h in unstimulated muscle explained a large proportion of the variation (R^2=0.71) at 72 h (D. Hopkins, unpublished data). The number of rams measured in each flock and their means for the various traits are shown in Table 2.

Hot carcass weights were recorded and the GR measured (total tissue depth over the 12th rib, 110 mm from the midline) using a GR knife. The number of rams slaughtered each year is shown in Table 2.

Table 2. Number of animals slaughtered each year

Year of birth	Numbers
1997	678
1998	370
2001	484
2002	503
2003	509

2004	411
Total	2955

After overnight chilling (4–5°C) the carcasses were cut between the 12th and 13th ribs and the m. *longissimus thoracis et lumborum* (LL) was exposed to the air at chiller temperature for 30 min. The meat colour was measured on the cut surface using a Minolta Chromameter (Model CR-300) set on the *L**, *a**, *b** system (where *L** measures relative lightness, *a** relative redness and *b** relative yellowness). The chromameter was operated using Illuminant C and a white tile standard (Y = 93.1, x = 0.3135, y = 0.3197). Three replicate measurements were taken at the same position with special effort to avoid areas of connective tissue and intramuscular fat. The pH of the LL was measured at the same site as the colour measurement after calibrating the metre at chiller temperature using a WPS meter with temperature compensation (TPS, WP-80, PTS Pty Ltd). The probe was a polypropylene spear-type gel electrode (Ionode IJ 44). The pH of the muscle *semitendinosus* (ST) was also measured. The fat depth overlaying the LL at the 12th rib was measured (FatC) as were the dimensions (depth and width) of the LL. The cross-sectional area of the LL was estimated by multiplying the depth by width by 0.8.

3.1.4 Statistical analysis

3.2 Methodology – Objective 3

3.2.1 Flock structure and management

The wethers used in this study were born in 2001 and 2002 at the Condobolin Agricultural Research and Advisory Station in central western New South Wales. The wethers represented 7 bloodlines comprising 2 superfine lines, 2 fine wool lines (2 only for 2002 drop animals, with 1 for 2001 drop animals), 2 medium wool lines and 1 broad wool line (only for 2001 drop animals). Each year, the ewes of each bloodline were joined to 2 rams of the same bloodline for the first cycle and a third sire added for the second cycle. Both drops of wethers were transported to the Orange Agricultural Institute (OAI) in the spring of 2002 and 2003 respectively at 15–16 months of age. The wethers were between 17–18 months old at slaughter and all had fully erupted permanent incisors classifying them as hoggets (Anon. 1998).

The wethers grazed pasture at OAI that consisted primarily of cocksfoot (*Dactylis glomerata*), Yorkshire fog (*Holcus lanatus*), phalaris (*Phalaris aquatica*) and tall fescue (*Festuca arundinacea*) grasses along with subterranean clover (*Trifolium subterraneum*). In 2002 the pasture had an average crude protein level of 7.1%, a ME of 6.5 MJ/kg DM and a digestibility of 46.7%. In 2003 the average crude protein level was 11.4%, the ME 8.2 MJ/kg DM and the digestibility 57.4%. The amount of available dry matter was determined to be about 2.5 t/ha in 2002 and up to 11 t/ha in 2003. In both years, the wethers were fed oats and lupins as an introductory feed to a formulated pellet which they were fed at pasture for 5 weeks before slaughter. The pellets comprised 30% lucerne, 20% lupins, 30% wheat and 20% oats with bentonite added. These pellets had an average crude protein level of 18.8%, a ME of 11.4 MJ/kg DM and a digestibility of 75.8%. The wethers were fed 1kg/head.day 3 times a week.

3.2.2 Slaughter procedures and measurements

The animals were yarded and held for 1.5–2 h before weighing the day before slaughter, then allowed to drink and graze pasture for 2–4 h before trucking to the abattoir, a trip of 100 km. At the abattoir the animals were held in yards overnight with access to water. Animals born in 2002 were randomly divided by bloodline into 2 slaughter groups and slaughtered within 1.5 h of each other. This was done to facilitate the collection of muscle samples soon after slaughter. A total of 123 wethers were slaughtered in 2002 and 219 in 2003 with the number per bloodline per year shown in Table 3.

Samples (about 5 g) of (LL) were taken on all carcasses (in 2003) below the 12th rib on entry to the chiller. Samples were taken within 1 h of death and frozen in liquid nitrogen and held at -80°C until assayed for selected enzyme activity. The same measures as for Trangie rams were also taken. The carcases were not electrically stimulated.

Table 3. Number of wether hoggets slaughtered over 2 years according to bloodline and strain

Bloodline	Strain	Numbers slaughtered	
		2002	2003
A	Broad	14	—
B	Medium	30	52
C	Medium	10	24
D	Fine	36	43
E	Fine	—	24
F	Superfine	27	50
G	Superfine	6	26

For assay of muscle enzymes, samples from 50 carcasses (2002 drop) were selected from the B (medium) and F (superfine) bloodlines (2 × 25) based on LL muscle pH values so as to cover the entire range in values. Before homogenisation, the muscle was pulverised at the temperature of liquid nitrogen and then homogenised using a Polytron at full speed in 20mM triethanolamine, 280mM sucrose, 1mM ethylenediamine tetra acetic acid, 1mM dithiothretiol, 100 μM phenylmethanesulphonylfluoride inhibitor, 2% Triton at pH 7.4. Samples were homogenised for 30 s, except those used for the determination of fructose 1,6-bis-phosphatase which were homogenised for 2.5 min in the same solution minus the Triton. The activity (μmoles/min.mg protein) of fructose 1,6-bis-phosphatase was determined using the procedure of Opie and Newsholme (1967) with the addition of a dialysis step to remove an inhibitor from the final homogenisation buffer. Lactate dehydrogenase (LDH) activity (μmoles/min.mg protein) was determined according to the procedure

of Ansay (1974) and isocitrate dehydrogenase (ICDH) activity by the method described by Briand *et al.* (1981). Myoglobin concentration was determined using the method of Trout (1991).

3.2.3 Statistical analysis

Data were analysed using a REML procedure (Genstat 2004), which contained the fixed bloodline effect (1–7), with year of birth included as a random term. For carcass traits, hot carcass weight was included as a covariate and for colour traits; muscle pH was used as a covariate.

4 Results

4.1 Results - Objectives 1 & 2

4.2 Results – Objective 3

A summary of differences between bloodlines for carcass traits is shown in Table ?. The notable finding was the much greater ($P < 0.001$) fat levels in the superfine bloodlines based on GR, with this also true for FatC measures in the superfine bloodline F ($P < 0.001$). Differences in LL muscle dimensions were minor, although bloodline A had a lower depth which translated into a smaller LL cross sectional area ($P < 0.05$).

Significant differences ($P < 0.001$) were detected between bloodlines for muscle pH with superfine animals having the highest values for the LL (Table ?). The differences for the ST were less consistent between bloodlines, but of the bloodlines the broad wool line had the lowest levels in both muscles. There were few differences between bloodlines for the meat colour traits measured on the loin muscle (Table ?). The correlation coefficients between colour the parameters *L**, *a**, *b** and pH were –0.23, –0.40 and –0.34, respectively.

Of the muscle enzymes examined, only ICDH was different between the 2 bloodlines, with muscle from bloodline B animals (medium) having significantly higher ($P < 0.05$) activity than muscle from bloodline F animals (superfine). The activities of LDH and ICDH were expressed on a per gram muscle basis and a per milligram protein basis to enable comparison with published studies (e.g. Juire *et al.* 1998).

5 Discussion

5.1 Discussion - Objectives 1 & 2

5.2 Discussion – Objective 3

5.2.1 Carcass and meat quality measures

Fogarty *et al.* (2003) sampled fine wool Merino hogget rams and found these were fatter than medium and broad wool types. Similar results were obtained in the current study using wethers. Similarly, Fogarty *et al.* (2003) found that there was no difference for LL muscle dimensions between strains. Our results are consistent with this result when differences in carcass weight are taken into account. Hopkins (1996) found that for the LL, lightness (*L**) values below 34 indicate dark meat as determined by consumers. In the present study differences between bloodlines were minimal and showed no particular pattern, whereas Fogarty *et al.* (2003) found that the fine wool strain produced lighter coloured LL than other strains. Muscle pH values measured by Fogarty *et al.* (2003) indicated animals with low levels of muscle glycogen (Gardner *et al.* 1999). To counter any tendency for low muscle glycogen, animals in the current work were supplemented with high energy pellets for 5 weeks before slaughter. To achieve an ultimate pH of 5.5, muscle needs to contain at least 50–60 µmol/g of glucose as glycogen immediately pre-slaughter to form sufficient lactic acid (Tarrant 1989). The absolute pH values in the LL of the hoggets in the current study were however higher than found in previous reports for Merino lambs (Hopkins and Fogarty 1998; Gardner *et al.* 1999; Hopkins *et al.* 2005) but the overall higher level in the ST is consistent with previous work Gardner *et al.* 1999; Hopkins *et al.* 2005). Across muscles it was apparent that animals with finer wool had higher muscle pH than stronger wool bloodlines, a result contrary to that of Fogarty *et al.* (2003) In this regard it should be stressed that Fogarty *et al.* (2003) did not test superfine bloodlines and the fine and medium wool strains had similar values in their work and we did not test many broad wool animals.

The observed difference in muscle pH in our study may reflect a higher intake of the supplement in the medium wool lines and thus a higher glycogen concentration, or a difference between bloodlines in the response of muscle glycogen under the same level of intake (Martin *et al.* 2004). Alternatively the response of the bloodlines to the stress of slaughter may differ having an impact on muscle metabolism. The tendency for the finer wool strains to produce higher pH meat does indicate a greater likelihood of a reduced shelf life (Egan and Bray 1988), but it was not considered fruitful to pursue this aspect of the work given that Sheep CRC work running in parallel at the time had objectives to understand the physiological/stress response in Merinos and to better understand the propensity for production of high pH meat (Warner *et al.* 2006). Although some of the findings were inconclusive it did emerge that meat from Merinos does discolor under retail display at a faster rate than meat from crossbred lambs particularly for leg cuts (Warner *et al.* 2006). It appears that the use of more highly muscled Merino rams can reduce the pH effect in progeny (Martin *et al.* 2004), but there are still some fundamental work to be undertaken to fully understand the physiological mechanism.

5.2.2 Muscle enzyme activity

The activity of LDH and ICDH have been used as indicators of the anaerobic and aerobic metabolism of muscle respectively (Juire *et al.* 1998), but the use of fructose 1,6-bis-phosphatase as an anaerobic indicator is new. Previous work in other mammalian species has shown expression exclusive to type IIB muscle fibres (Opie and Newsholme 1967). Myoglobin levels tend to be higher in more aerobic muscle (Swatland 1994) and were also measured for this reason. For comparison with other results in the literature the activities have been defined in terms of min./per.muscle (Juire

et al. 1998; Serra *et al*. 2004). Activity can also be defined in terms of the amount of protein and the results in Table 2 indicate that the significance of the differences between bloodlines were the same irrespective of how activity was defined. The ratio of LDH to ICDH has been used as an indication of muscle glycolytic capacity (Serra *et al*. 2004). The activity of ICDH was higher in the LL muscle from animals of bloodline B indicating greater aerobic capacity irrespective of how activity is defined; however there was no difference in myoglobin level. The myoglobin level was higher in the LL of the Merino hoggets in the current study than the Merino lambs studied by Hopkins *et al*. (2005). This is in agreement with the concept that pigment increases as animals age (Ledward and Shorthose 1971). The significantly lower muscle pH for bloodline B was mirrored by a lower glycolytic capacity expressed as the LDH/ICDH ratio with a correlation of 0.46 and a negative correlation of 0.41 with ICDH activity. This indicates the LL of bloodline B animals was relatively more oxidative.

Jurie *et al*. (1998) found that the ST muscle has lower ICDH activity than the LL in cattle and it has been reported many times that the ST in lambs has a higher ultimate pH than the LL (e.g. Gardner *et al*. 1999; Hopkins *et al*. 2005). Therefore, the fact that the LL muscle from B bloodline animals had a lower mean pH and higher ICDH activity appears consistent with previous observations.

Muscles consist of distinct fibre types that can be conveniently differentiated on the basis of their contractile and metabolic properties. They are: (i) slow-twitch oxidative fibres (type I); (ii) fast-twitch oxidative-glycolytic fibres (type IIa); and (iii) fast-twitch glycolytic fibres (type IIb) (Peter *et al*. 1972). Type I fibres have a low glycolytic capacity compared with type IIa fibres. Type IIb fibres have the highest glycolytic capacity (Lister 1989). With slow rates of glycogen synthesis type IIb fibres are the most susceptible to stress induced glycogen depletion (Monin 1981). These differences can be largely explained by the different enzyme compliment of each fibre type of mammals (Saltin and Gollnick 1983). Thus the very high activity of glycogen phosphorylase in combination with low activities of glycogen synthase and hexokinase mean that muscle groups with an increased ratio of anaerobic to aerobic capacity will more rapidly deplete and more slowly replete glycogen levels. Clear evidence for this effect was shown by Gardner *et al*. (2001) where the more aerobic *m. semimembranosus* showed a strong linear relationship between the extent of glycogen repletion during a 72 h period after exercise depletion whereas the more anaerobic ST muscle showed no significant repletion during the same time period. In the current study the differences between the 2 bloodlines in terms of enzyme activities are consistent with such a change in the ratio of anaerobic to aerobic capacity within the same muscle type. In fact, although not significant, the trend for a lower activity of fructose 1,6-bis-phosphatase in muscle from bloodline B supports this contention. These results tentatively suggest that there may be a difference in fibre type frequency in the LL muscle of the two bloodlines and this appears to impact on muscle pH. There is however strong evidence that the metabolic pattern of energy metabolism within muscle, pre-slaughter nutrition and stress interact to determine the final concentration of glycogen within muscle at slaughter (Pethick *et al*. 2005). As such an increased anaerobic energy metabolism of muscle is associated with a greater chance of low glycogen at slaughter, especially when nutrition is below that required for positive growth. It has also been shown that double-muscled cattle show a more anaerobic metabolism than normal muscle cattle (Sudre *et al.* 2005) and are more sensitive to stress. Similarly genetic lines of sheep which show increased muscle development need a higher nutritional input to achieve elevated glycogen stores within muscle (Martin *et al*. 2004). It is also possible that the pattern of energy metabolism as reflected by changes in enzyme activity may occur without changes in fibre type frequency.

Whether the activities of these enzymes explains the propensity for Merinos to produce higher muscle pH values (Hopkins and Fogarty 1998; Gardner *et al*. 1999; Hopkins *et al*. 2005) when

slaughtered under commercial conditions is not completely clear as there are no comparative data for non Merinos. What is of interest is the absolute ICDH activity which is double that reported by Jurie *et al*. (1998) for LL muscle from young Saler and Limousin bulls. In contrast LDH activity was lower in the sheep LL of the current study than reported by Jurie *et al*. (1998) in LL from cattle. These differences are also apparent when the results of Serra *et al*. (2004) for young Brown Swiss bulls are compared with the results of the current study. In this regard it is worth noting that the pH of the LL reported by Serra *et al*. (2004) was 5.56, which is much lower than found in the current study.

6 Success in Achieving Objectives - Section

6.1 Success in Achieving Objectives - Heading

6.1.1 Success in Achieving Objectives - Sub Heading

7 Impact on Meat and Livestock Industry – now & in five years time - Section

7.1 Impact on Meat and Livestock Industry – now & in five years time - Heading

7.1.1 Impact on Meat and Livestock Industry – now & in five years time - Sub Heading

8 Conclusions and Recommendations - Section

8.1 Conclusions and Recommendations – Objectives 1 & 2

8.1.1 Conclusions and Recommendations - Sub Heading

8.2 Conclusions and Recommendations – Objective 3

Superfine bloodlines produced the fattest carcasses with the differences between bloodlines reflecting differing mature weights. The loin muscle from hoggets is darker than lamb loins and this will significantly reduce the retail value of such meat, but in this study there was no apparent effect of bloodline on loin colour. Given the high pH of Merino hogget meat, shelf life will be compromised and it appears that lowered aerobic metabolism in muscle may be the cause of this propensity for a high pH. The issue of high pH meat in merinos has been the subject of research in the Sheep CRC

and it appears there may be some scope to lower this by selection for muscle depth with high levels of nutrition pre-slaughter.

9 Acknowledgements

9.1 Objectives 1 & 2

9.2 Objective 3

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11 Appendices

11.1 Appendix 1

The Merino flock being studied within the QPLU$ project consists of 9 selection lines within the fine (based on Merryville bloodline), medium (based on Haddon Rig bloodline) and broad (based on East Bungaree bloodline) strains as described in Table 1. These lines were established in 1995, following matings within a fully pedigreed foundation flock during 1993 and 1994. Until 1998, all selection pressure applied was through the rams selected as sires with each line. Rams were selected across three age groups while ewes were selected across six age groups. In successive years, about 30% of ewes have been culled from each line. Selection continued for a total of 10 rounds, with the final drop born in 2004.

Table 1. The QPLU$ selection lines.

Strain	Selection Line	Description of Breeding Objective
Fine	***8% MP***	Equal emphasis on reduced fibre diameter and increased fleece weight
	Control	Randomly selected line that represents the original population
Medium	***3% MP***	Maintain fibre diameter and maximise increases in fleece weight
	8% MP	Equal emphasis on reduced fibre diameter and increased fleece weight
	15% MP	Maintain fleece weight and maximise reduction in fibre diameter
	Industry	Reduce fibre diameter by 0.5 microns, increase fleece weight and improve wool quality and conformation
	Control	Randomly selected line that represents the original population
Broad	***8% MP***	Equal emphasis on reduced fibre diameter and increased fleece weight
	Control	Randomly selected line that represents the original population

- The 5 selection lines that are named 3% MP, 8% MP and 15% MP are selected using an index of fleece weight and fibre diameter. The percentage figures refer to the micron premium on which they are based, which in turn reflect different emphases on fleece weight and fibre diameter. Micron premium is simply a measure of the relative increase in price per kg of wool

that would result from a 1 micron reduction in fibre diameter (an 8% micron premium means that 1 micron finer wool would attract an 8% price premium).

- The Industry line is being bred to an objective set by the QPLU$ Industry Liaison Committee. This is a committee of ram breeders, classers and wool producers whose objective is to reduce fibre diameter by 0.5 micron, increase fleece weight and improve wool quality and conformation. Selections are made by prominent stud classer, Mr John Williams. The Industry line sheep are ranked according to an index that has been developed to meet their objective and Mr Williams uses this ranking in combination with his own visual assessment to make selections.
- The Control lines are randomly mated to represent the foundation sheep from which the first selections were made. In addition, semen from the foundation sires was stored so that at the end of the project, the top sires produced by 10 years of selection can be compared with their starting point.

11.2 Appendix 2

Publications arising from project

Hopkins, D. (2003). Meat and wool traits, Feedback, MLA, Sept, p7.

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