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# Australian sheep breeding values for carcass traits may alter muscle distribution in lamb carcasses

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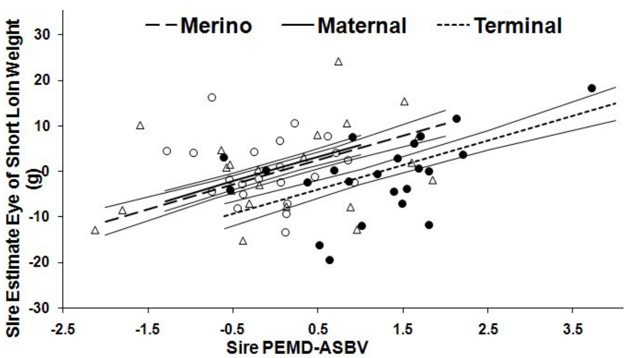
**SUMMARY**

The financial value of a carcass is determined by lean meat yield, which is in turn determined by weight and composition. Carcass composition is greatly affected by fatness, which poses a significant processing cost (Jones *et al.* 2002). Australian lamb producers select livestock indirectly for lean meat yield percentage via three Australian sheep breeding values (ASBVs) that are determined on the live animal: post weaning weight (PWWT), C-site fat depth (PFAT) and eye muscle depth (PEMD). The authors of a previous study hypothesised that an increase in PWWT and PEMD and a decrease in PFAT will increase lean meat yield percentage (Gardner, G. E. unpubl. data). They used data from an Information Nucleus Flock that consisted of lambs from sires with extreme ASBVs for several production traits. The carcasses of approximately 2000 lambs from the 2007 cohort were assessed after slaughter at a target weight of 21.5 kg, 352 of which underwent computed tomography (CT) scanning to determine proportions of bone, muscle and fat. The results only partially supported the original hypothesis, in that a decrease in PFAT ASBV increased CT lean percentage and decreased CT fat percentage. An increase in PWWT ASBV increased carcass weight but did not alter CT lean percentage. Likewise, an increase in PEMD ASBV did not alter CT lean percentage but increased the weight of the loin (Figure 1), the site at which PEMD is measured on the live animal. Therefore, we hypothesise that a high sire PEMD ASBV is associated with redistribution of muscle tissue to the loin and away from other muscle depots without changing whole carcass lean percentage. As the carcasses were scanned after dissection into fore, mid, and hind sections, future analyses of these carcasses will compare the distribution of bone, muscle and fat between these sections using a log:log form of the allometric equation $y = ax^b$. This will be analysed as a linear function log, $y = a + b\log x$, where y = tissue (e.g., muscle) weight within a section and x = total weight of the tissue type within the carcass. The term $a$ is the proportionality coefficient and $b$ is the growth rate of $y$ relative to $x$. Localised changes in muscle tissue distribution may alter carcass value despite the absence of a change in lean meat yield given that an increase in loin weight adds mass to the most expensive cut in the carcass. The weights of the topside, loin and round were recorded at slaughter, which may enable ASBVs to be developed for selection for increased lean percentage in the more valuable hindquarter cuts. Concern remains that selection for leanness may affect eating quality, and therefore correlations between CT lean percentage and traits such as intramuscular fat percentage, muscle metabolic type and mineral content (Fe, Zn) will be determined.

**Figure 1.** Relationship between sire estimate for weight of eye of short loin (g) and sire PEMD-ASBV for Merino (Δ) maternal (○) and terminal (● ) sires. Lines are LS means ± S.E. (Gardner *et al.* unpubl. data)

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# How robust are genomic selection methods?

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**SUMMARY**

Genomic information from many single nucleotide polymorphism (SNP) markers can be used to increase the accuracy of estimated breeding values of young animals. This is termed genomic selection (GS) and is based on prediction of the effects of quantitative trait loci (QTL) in linkage disequilibrium (LD) with markers (Meuwissen *et al*. 2001). However, Habier *et al.* (2007) proposed that GS also relies on "relationships" between individuals to accurately predict genetic value. A better understanding of what GS actually predicts is needed to develop marker panels, training populations and methods for accurately estimating breeding values. The efficacy of methods used to predict genomic breeding value may depend on the underlying model of genetic variation, which is not well known. The aim of this study was to determine the accuracy and robustness of various methods used for genomic selection using a range of underlying genetic models and to compare the accuracy of GS when predicting one generation ahead (training set 1), several generations ahead (training set 2) or across different populations (training set 3).

Three models of variation were used to simulate the genetic value of animals: (i) a QTL model in which few QTLs have a relatively large effect, (ii) a QTL model in which many QTLs have moderate effects and (iii) an infinitesimal model in which very many QTLs each have a very small effect. Genotype information from 60,000 markers was used to estimate the genetic value of animals using the following methods: (a) Bayes B, based on estimation of marker effects, (b) gBLUP, based on genomic relationships between animals and (c) traditional BLUP, based on pedigree relationships.

**Table 1. Average correlation between estimated and true breeding values using 60,000 SNP markers and training sets one generation away (1), eight generations away (2) or from another sub-population (3)**

| Genetic Model of Variation | Training Set | Bayes B | gBLUP | BLUP |
|---|---|---|---|---|
| 100 QTLs | 1 | 0.83 | 0.56 | 0.46 |
| | 2 | 0.77 | 0.37 | |
| | 3 | 0.77 | 0.33 | |
| 1000 QTLs | 1 | 0.65 | 0.59 | 0.47 |
| | 2 | 0.49 | 0.38 | |
| | 3 | 0.47 | 0.34 | |
| Infinitesimal | 1 | 0.39 | 0.40 | 0.45 |
| | 2 | –0.01 | 0.00 | |
| | 3 | 0.00 | –0.01 | |

The Bayes B method was the most accurate method for predicting breeding value when there were 100 QTLs and resulted in accuracies similar to those obtained with gBLUP when the infinitesimal model was used. Both genomic methods relied on both relationships and QTL effects to estimate breeding values. Large QTL effects enabled prediction of breeding value regardless of whether animals were related. However, with the infinitesimal model, prediction was based on relationships and none of the methods were able to predict breeding values when the animals were unrelated. We conclude that the Bayes B method is the superior method as it utilizes large QTL effects if they exist, resulting in accurate genomic EBVs, whereas it relies on relationships in the absence of large QTL effects, becoming equivalent to the BLUP method.

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# Myostatin mutant heterozygote sheep need good nutrition

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## SUMMARY

The myostatin mutation, +g6723G>A, is associated with a high yield of high quality lamb meat (Kijas *et al*. 2007). Myostatin negatively regulates skeletal muscle growth. The +g6723G>A mutation reduces the production of myostatin, increasing carcass muscle content and decreasing carcass fat content. We investigated whether nutrient supply (feed intake) affects the expression of muscle and fat traits in wether lambs with one or no copy of the myostatin +g6723G>A mutation.

Seventy-eight wether lambs with one ($n$ = 38, MSTN A/G) or no copies ($n$ = 40, MSTN G/G) of the causative allele were housed in individual pens and fed a diet at a high or a low level (1.8 or 1.1 × maintenance allowance, respectively) for 47 days. The lambs were subjected to computed tomography scanning at the beginning and completion of the experiment. The non-carcass components in each image were removed and the weight of lean tissue (muscle), fat and bone were estimated using Autocat software, as described by Haynes *et al.* (2010). The data were analysed using a linear regression model using R (R development core team, Vienna, Austria) to test the effects of myostatin genotype and nutritional level and their interaction, with initial composition as a covariate.

All lambs had a greater rate of fat deposition than muscle deposition (Table 1). The heterozygous lambs had a greater ($P$ < 0.05) daily carcass growth rate and a tendency ($P$ < 0.10) to deposit more lean tissue than the homozygous normal lambs when fed *ad libitum*. In contrast, heterozygous lambs had the slowest carcass and muscle ($P$ < 0.10) growth when feed was restricted. Accretion of bone differed ($P$ < 0.05) only between feed levels not genotype.

**Table 1. Average daily growth (g/day) of muscle, fat, bone and the total carcass of lambs heterozygous or homozygous for the MSTN A/G mutation when fed *ad libitum* or at a low level**

| Variable (g/d) | High feed intake | | Low feed intake | |
|---|---|---|---|---|
| | MSTN A/G | MSTN G/G | MSTN A/G | MSTN G/G |
| *n* | 19 | 19 | 20 | 20 |
| Fat | $99.2 \pm 2.5^{\mathrm{a}}$ | $96.3 \pm 2.5^{\mathrm{a}}$ | $25.5 \pm 2.4^{\mathrm{b}}$ | $26.4 \pm 2.4^{\mathrm{b}}$ |
| Muscle | $81.0 \pm 5.0^{a}$ | $70.0 \pm 5.0^{b}$ | $2.6 \pm 4.8^{c}$ | $8.4 \pm 4.9^{c}$ |
| Bone | $9.0 \pm 0.8^{\mathrm{a}}$ | $7.7 \pm 0.8^{\mathrm{a}}$ | $1.4 \pm 0.8^{\mathrm{b}}$ | $1.9 \pm 0.8^{\mathrm{b}}$ |
| Total | $189.2 \pm 5.6^{\mathrm{a}}$ | $174.0 \pm 5.6^{\mathrm{b}}$ | $29.5 \pm 5.4^{c}$ | $36.7 \pm 5.4^{d}$ |

Row means with different superscript letters differ ($P$ < 0.05) or tend to differ ($P$ < 0.10, italics).

A high plane of nutrition improved the growth rate of the heterozygous MSTN A/G lambs more than that of the homozygous normal lambs; however, nutritional restriction adversely affected the heterozygous lambs more than the homozygous normal lambs. Hence, sheep heterozygous for the myostatin mutation require a high level of nutrition to maximise the genetic benefits of this mutation.

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# Lambs sired by rams with low Australian Sheep Breeding Values for C-site fat depth have superior efficiency during finishing

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**SUMMARY**
Lambs may be subjected to periods of nutrient restriction. In cattle, such restriction limits their ability to meet market specifications (Greenwood and Cafe 2007). Ryan *et al.* (1993) demonstrated that feed-restricted wether lambs showed no change in feed conversion ratio (FCR) and Owens *et al.* (1995) demonstrated that lean tissue development is more efficient than growth of fat tissue. Therefore, we hypothesised that pre-weaning nutritional restriction would not affect feed efficiency during finishing and that a reduction in sire post-weaning C-site fat depth (PFAT) Australian Sheep Breeding Value (ASBV) would improve lamb efficiency during finishing. To achieve a nutrient restriction prior to weaning, we assessed twin *v.* single lambs. Two groups of lambs were finished: the average age at finishing of group 1 was 210 days (n = 40) and that of group 2 was 252 days (n = 35). Group 1 consisted of the heaviest lambs at weaning and group 2 the lightest lambs at weaning. Groups were balanced for sire, sex and numbers of twin- and single-born lambs. The lambs were the progeny of 13 sires that varied in PFAT ASBV(–1.59 to 0.3). Lambs were group-housed during finishing, fed a pelleted diet (13.5 MJ ME/kg dry matter, 16.7% crude protein) and individual feed intakes were recorded. Liveweight change and individual feed intake were used to calculate FCR. Single ewe lambs had a better FCR (about three FCR units) than twin ewe lambs ($P < 0.05$), a difference that was not evident in wethers (Fig. 1*a*). Lambs from group 1 were about nine FCR units more efficient ($P < 0.05$) than group 2 lambs, and within both groups, a decrease in sire PFAT of 1.5 mm improved ($P < 0.05$) lamb efficiency by about five FCR units (Fig. 1*b*).

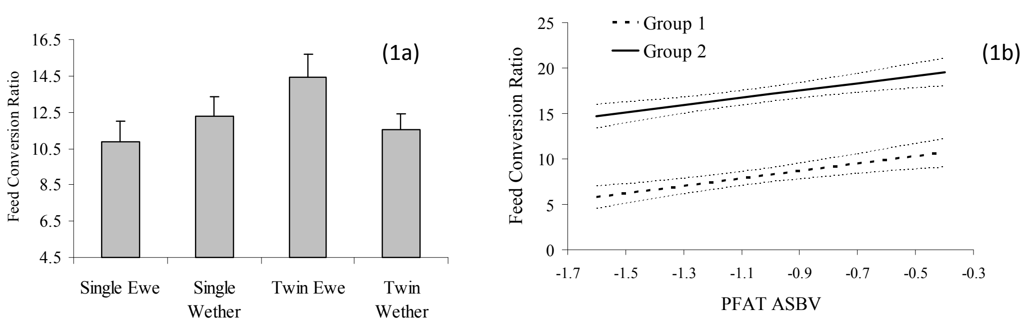


**Figure 1.** Effect of lamb sex and birth/rear type (*a*) and sire PFAT Australian Sheep Breeding Value (*b*) on feed conversion ratio (kg feed per kg liveweight gain) during finishing.

In contrast to our first hypothesis, twin ewe lambs were less efficient than single ewe lambs. However, the lack of a difference in FCR of wether lambs is consistent with Ryan *et al.* (1993). In support of our second hypothesis, lambs sired by leaner sires were more efficient during finishing in groups 1 and 2, which was probably associated with differences in the efficiency of lean tissue accretion (Owens *et al.* 1995). We are uncertain as to why there is divergence in the efficiency of groups 1 and 2, but it may be associated with stage of maturity. These results show that the current practice of selecting rams with low PFAT will improve FCR, and that an early restriction will affect the FCR of twin ewe lambs during finishing.

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# Growth rate, muscling and reproduction in Merino ewe lambs

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## SUMMARY

To meet projected demand for lamb meat, weaning rates in the Merino flock must be improved. Lambing of replacement ewes at 12–14 months of age rather than at 24 months of age will increase the number of lambs produced and is likely to increase the profitability of lamb production systems if the reproductive rate is sufficiently high (Young *et al.* 2010). Merino ewe lambs can be successfully joined if they have adequate liveweight at joining, but little is known about how genetic factors that control weight gain influence reproductive success. As growth, muscling genotype and fecundity are positively correlated in adult Merino ewes (Ferguson *et al.* 2007), we tested the hypothesis that Merino ewes with higher genetic potential for growth and muscling would be more able to reproduce at younger ages.

For 136 Merino ewe lambs that were born between August and September 2009, we recorded liveweight (LW) weekly and used ultrasonography to measure back fat and eye muscle depth at average ages of 164 and 251 days. The data were used to generate Australian Sheep Breeding Values (ASBVs) at post-weaning age for weight (PWT), depth of eye muscle (PEMD) and fat (PFAT). Teasers were introduced when the ewe lambs were on average 179 days old and 37 ± 0.4 kg LW. Ewes were allocated to 8 groups and teasers were replaced with rams when the ewe lambs were on average 249 days old and 41 ± 0.5 kg LW. Age at first oestrus was recorded when ewes were marked by either a teaser or a ram and pregnancy was determined by ultrasound 40 days after ram removal. Data were analysed using a linear mixed model for age at first oestrus and a generalised linear mixed model with a binomial distribution and a logit-link function for the proportion pregnant. In total, 127 (93%) of the ewe lambs displayed oestrus during the experiment and 97 (71%) of ewes conceived. Ewe lambs with a higher PWT displayed first oestrus at a younger age ($P < 0.05$; Fig. 1*a*) and were more likely to conceive ($P < 0.01$; Fig. 1*b*) than ewe lambs with a lower PWT. There was no significant effect of PEMD or PFAT on age at first oestrus or on fertility.

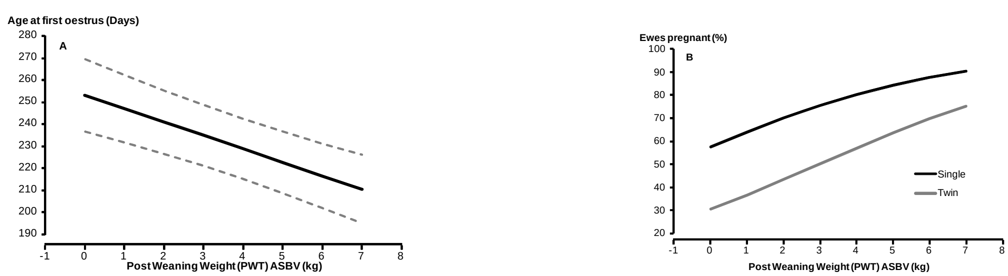


**Figure 1.** Relationships between ASBV for post-weaning weight (PWT) and (*a*) age at first oestrus and (*b*) percentage of ewes pregnant.

We conclude that selection of animals for improved growth (high PWT) will improve the success of mating in ewe lambs, adding to the other known benefits of selection for growth in terms of improving the profitability of lamb production systems.

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# Accuracy of genomic selection in predicting carcass traits in meat sheep

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**SUMMARY**

Australia's red meat supply chains are shifting from supplier-driven production to consumer-driven demand. The ability of the red meat supply and demand chain to allocate animals to end-users will be determined by the increase in phenotype prediction accuracy (for allocation of animals to specific slaughter cohorts or consumer markets) and the increase in breeding value accuracy (genome-assisted selection of breeding animals).

The aim of this study was to determine the accuracy of predicting phenotype for the following carcass and growth traits: hot carcass weight (HCWT, kg), cold eye-muscle area (CEMA, $cm^2$) and intramuscular fat percentage (IMF). The three statistical models were used: 1) fixed effects only, 2) fixed effects and additive genetic polygenic effects (pedigree) and 3) fixed effects, pedigree and genotypic data (50 K single nucleotide polymorphisms [SNPs]). The fixed effects models included management group, breed, gender, birth and rear type, season and age. Variance components and heritability were estimated using ASReml (Gilmour *et al.* 2002). We used the BayesB model (Meuwissen *et al.* 2001) with a strong Bayesian prior for proportion of SNPs included in the model and set at 1%. Cross validation (Kohavi 1995) was performed for 8 replicates using training data, which included 75% of the data, and validation data, which comprised the remaining 25%. Three scenarios were tested for prediction accuracy by choosing training and test sets either randomly, across sire families or across breeds. We calculated correlations between predicted and observed phenotypes. The accuracy of predicting breeding value can be approximated from our results by taking the incremental variance explained due to fitting SNP data as a proportion of the variance not explained by fixed effects multiplied by trait heritability.

**Table 1. Accuracy of predicted and observed phenotypes for carcass weight, eye muscle area and intramuscular fat**

| Trait | Model | Random | Across sire | Across breed |
|---|---|---|---|---|
| HCWT | Fixed effects | 0.69 | 0.66 | 0.60 |
| | Fixed + Poly G | 0.71 | 0.72 | 0.60 |
| | Fixed + Poly G + SNP | 0.74 | 0.74 | 0.64 |
| CEMA | Fixed effects | 0.51 | 0.54 | 0.52 |
| | Fixed + Poly G | 0.60 | 0.62 | 0.51 |
| | Fixed + Poly G + SNP | 0.77 | 0.70 | 0.60 |
| IMF | Fixed effects | 0.57 | 0.42 | 0.39 |
| | Fixed + Poly G | 0.57 | 0.44 | 0.40 |
| | Fixed + Poly G + SNP | 0.58 | 0.44 | 0.39 |

Table 1 shows that accuracy was higher when predicting within random subsets than across sire families, and lowest when predicting across breeds. The derived accuracy of predicting breeding values was 0.45, 0.72 and 0.32 for HCWT, CEMA and IMF, respectively, but these values were reduced when predicting across sire or breed. The use of genomic data would increase the accuracy of both phenotypic prediction and genomic selection.

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# The effect of triiodothyronine on mean retention time of rumen digesta and methane production in sheep

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**SUMMARY**

Global warming has recently become an important issue throughout the world and one of the major known contributors to this phenomenon is methane from agricultural ruminant livestock production (IPCC 2007). The mean retention time (MRT) of rumen contents in ruminants is positively correlated with the amount of methane produced by the microbial methanogens it contains (Pinares-Patiño *et al.* 2003). Endocrine factors may affect MRT via their effects on rumen contractions, which determine the retention time of feed particles within the forestomach (Bueno *et al.* 1972, Baile *et al*. 1986, Reid *et al*. 1988, Reid *et al*. 1991, Groenewald 1994). It was hypothesised that the thyroid hormone, triiodothyronine ($T_3$), the level of which is elevated during cold conditions and is known to influence metabolic rate, will modify reticulorumen and reticulo–omasal orifice contractions, reducing MRT and consequently, the amount of methane produced and emitted.

Ten 3-year-old wethers will be penned individually in temperature-controlled rooms at 20°C and fed a lucerne/wheaten chaff ration at 1.2 × maintenance. Five animals will be randomly allocated to each of two groups: one group will receive daily intramuscular injections of $T_3$ (7 µg/kg) and one group will receive saline injections. On completion of analysis, the saline group will receive $T_3$ and vice versa and measurements will be repeated.

Methane emissions will be analysed and MRT will be measured using non-digestible markers. Urine samples will be analysed for concentrations of purine derivatives and nitrogen and rumen samples will be analysed for rumen pH, volatile fatty acid levels and numbers of protozoa. Daily blood samples will be collected to assess $T_3$ titres and oxygen consumption will be monitored for changes in metabolic rate.

If the effect of $T_3$ on MRT and methane yield is significant, it may be possible to develop a biological marker for high and low methane-yielding ruminants.

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# Liveweight variation across annual cycles is lower in high growth rate ewes

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**SUMMARY**
Resilience of mature ewes to restricted nutrition is important as resilient ewes will be in better condition at mating and throughout pregnancy, which is associated with subsequent reproductive performance (fertility, fecundity and lamb survival). The innate ability of some ewes to maintain liveweight (LW) when nutrition is limited is likely to improve the profitability of sheep enterprises by reducing the cost of maintaining ewes over summer or by enabling higher stocking rates, particularly in environments characterised by large seasonal fluctuations in pasture supply. Adams *et al.* (2002) found that a heavier strain of Merino ewe lost less LW when grazed on dry, poor-quality summer pasture, suggesting that genetic potential for high growth rate may affect LW fluctuation. We hypothesised that the LW of adult ewes with high Australian Sheep Breeding Values (ASBVs) for hogget weight (HWT) will fluctuate less between seasons. Weight data from six Information Nucleus Flock sites for 1079 ewes from the 2007 and 2008 lambing seasons was analysed. All ewes were weighed at intervals throughout their lives, resulting in 10,948 hogget and adult observations. Weights recorded between day 100 of pregnancy and lambing were excluded from the dataset to remove bias due to conceptus weight, and differences between minimum and maximum weights in each reproductive cycle were determined for each ewe. These differences were analysed using a linear mixed-effects model with fixed effects for site, breed (Merino and Border Leicester × Merino) within flock, reproductive cycle ($1^{st}$ or $2^{nd}$), covariates for average LW of the reproductive cycle, HWT ASBV, C-site fat depth (HFAT) ASBV and random terms for sire and dam. Fluctuation in ewe LW differed significantly ($P < 0.0001$) between sites and was greatest at Katanning (Fig. 1*a*). HWT was negatively related to LW fluctuation, which decreased by 7.5 kg across the range of HWT ASBVs (–6.0 to 16.0). This was only evident in ewes in their second reproductive cycle (Fig. 1*b*). An increase in HFAT ASBV resulted in a decrease in weight fluctuation at some sites, particularly at the Cowra and Rutherglen sites, where variation decreased by 12 kg across the range of HFAT ASBVs (–4.5 to 4.5).

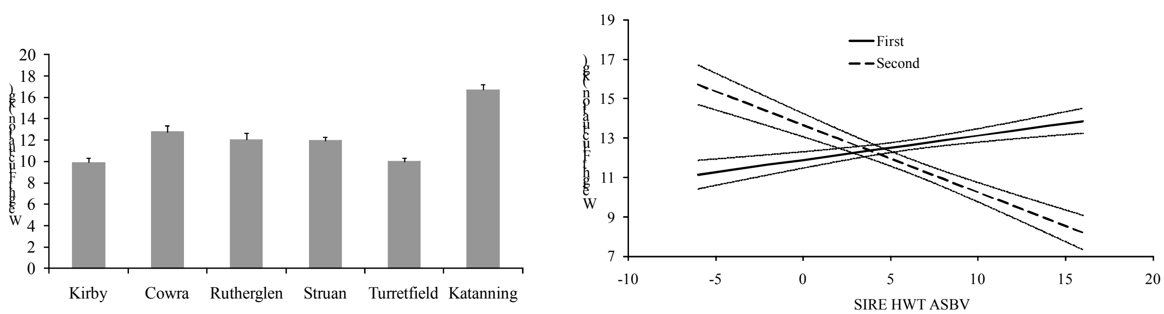


**Figure 1.** Average LW fluctuation according to (a) site and (b) sire HWT ASBV in the first and second reproductive cycles.

In support of our hypothesis, the amplitude of LW fluctuation was reduced as HWT ASBV increased. The lack of an effect in the first reproductive cycle is most likely because the ewes were still growing, which would have confounded weight fluctuations, particularly in high HWT ewes. Thus, selection for HWT ASBV may improve resilience in adult ewes but this effect is not evident in growing ewes. HFAT ASBV affected LW fluctuations at some sites but not at others. The reason for this is unknown but it may be related to nutrition.

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# Determining lamb growth rate during development

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**SUMMARY**

Lamb growth rate is an important determinant of on-farm productivity and profitability. Growth rate varies according to stage of development, which causes variation in meat quality traits. Therefore, developmental traits such as muscle metabolic type and intramuscular fat content are likely to be influenced by early and midlife growth, whereas traits such as the transient storage of muscle glycogen are more likely to be aligned with pre-slaughter growth (Pethick *et al.* 2004). An accurate model of all phases of growth is necessary to predict the effect of growth rate on meat quality traits.

Lamb growth can be modelled using the Brody function, the parameters of which describe birth weight, average mature weight and maximum growth rate at a given time (Brody, 1945). The Brody function did not predict growth in the weeks immediately before slaughter accurately because the weight of lambs within several management groups plateaued when pasture dried off and then increased rapidly when they were finished on grain (Figure 1). Cubic polynomial functions can be used to provide a more precise fit for pre-slaughter growth because they offer greater flexibility in simulating a late rapid increase in liveweight. Therefore, it was hypothesised that a cubic function would fit the liveweight data of these lambs with greater precision than a Brody function.

Lambs ($n$ = 3399) born in 2007 at seven sites of the Information Nucleus Flock experiment were weighed throughout their grow-out period, resulting in 32,159 observations. Brody and cubic functions were fitted to the liveweight data of each lamb and residual weights (difference between the observed and predicted weights) were analysed using a general linear model with age (week) as a fixed effect, adjustments for site, sex, birth type-rear type, sire type, dam breed within sire type and management group within site, and random terms for sire and dam.

When the standardised sums of squared errors were compared, the cubic function was superior to the Brody function (3.36 *v.* 6.40, respectively; Figure 2). During late growth (days 301–450), the error associated with the Brody function was larger than that associated with the cubic function (15.98 *v.* 6.49, respectively) but the errors of both functions were high, indicating that neither function fitted the data well.

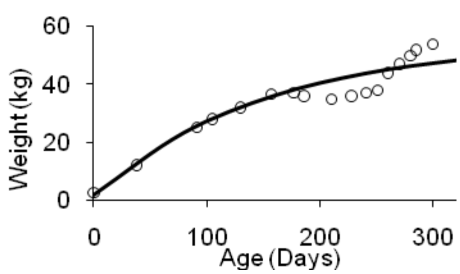


**Figure 1.** Brody function fitted to the liveweight data of an individual lamb

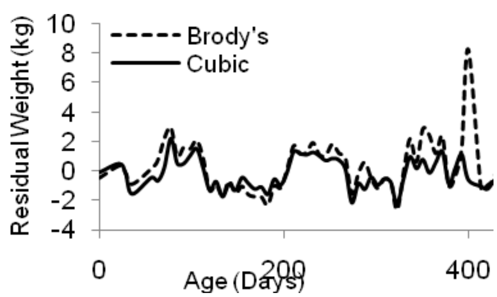


**Figure 2.** Average residual values for the Brody and cubic functions fitted to liveweight data for all lambs.

The cubic function provided a better fit to the liveweight data than the Brody function. The relatively poor fit of both functions to data from some management groups during the late growth phase indicates that further modelling is required for these sites.

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# Profit is maximised in a Merino prime-lamb enterprise when mature size is 60–70 kg

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**SUMMARY**

Ewe size at maturity affects whole-farm profitability. Firstly, because mature size is positively correlated with growth rate, selection for rapid growth results in a higher mature size. Secondly, larger ewes have higher maintenance requirements. Therefore, a trade-off exists between higher income from larger lambs and the cost of maintaining larger ewes. We hypothesize that whole-farm profit decreases as ewe mature size increases because of higher ewe maintenance costs.

To examine this trade-off, we constructed a whole-farm representation of a sheep enterprise in Hamilton, Victoria, using the 'AusFarm' simulation tool (Moore *et al*. 2007). The enterprise was simulated from 1965 to 2005 using historical weather information. The enterprise was 770 hectares in size and had 19 paddocks, three land classes that differed in soil type and slope and perennial ryegrass and subterranean clover pastures. The sheep system consisted of Merino ewes mated to Merino rams in mid-February for a mid-July lambing. Non-pregnant ewes were sold after pregnancy scanning and a proportion of ewe lambs were retained as replacements and mated at 7 months of age. Lambs were sold when they reached slaughter weight or were weaned and entered a feedlot if the specified weight was not achieved before the pasture quality declined. A full economic budget was calculated for each year.

We tested four stocking rates (8, 10, 12 and 14 ewes per hectare), four mature sizes (50, 60, 70 and 80 kg at condition score 3.0), three reproductive rates (100, 125 and 150 lambs per 100 ewes) and three lamb slaughter weights (45, 50 and 55 kg liveweight). Wool production was 5 kg greasy fleece weight, 20 microns fibre diameter and 70% yield. The highest profit ($885) was achieved with 14 ewes per ha, 60 kg mature size, 150% reproductive rate and a lamb slaughter weight of 50 kg. In general, profit was maximised when stocking rate was 12–14 ewes per ha, ewe mature size was 60–70 kg, reproductive rate was 125–150% and lambs were marketed at 45–50 kg liveweight (Table 1).

**Table 1. Gross margins ($/ha), ewe supplement cost (ewe supp cost) and lamb finishing supplement cost (lamb finish cost) for various scenarios**

| Mature size (kg at CS 3) | Gross margin ($/ha) | Ewe supp cost ($/ha) | Lamb finish cost ($/ha) | Stocking rate (ewes per ha) | | | | Reproduction rate (lambs per 100 ewes) | | | Lamb slaughter weight (kg liveweight) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8 | 10 | 12 | 14 | 100 | 125 | 150 | 45 | 50 | 55 |
| 50 | 543 | 73 | 143 | 391 | 497 | 594 | 689 | 488 | 558 | 582 | 603 | 531 | 494 |
| 60 | 686 | 93 | 48 | 518 | 642 | 765 | 820 | 616 | 704 | 739 | 685 | 699 | 675 |
| 70 | 702 | 111 | 13 | 567 | 700 | 799 | 787 | 621 | 712 | 752 | 680 | 708 | 721 |
| 80 | 683 | 160 | 10 | 613 | 694 | 767 | 661 | 598 | 694 | 713 | 650 | 691 | 707 |

The hypothesis was supported as profit decreased at a mature size of more than 70 kg because of a high ewe supplement cost. However, profit decreased at mature sizes of less than 60 kg because of high lamb supplement costs. The optimum mature size is 60–70 kg, at which ewe supplement costs and lamb finishing costs are balanced.

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# Management and selection potential in commercial sheep

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**SUMMARY**
The advantages of collecting various measurements and using genetic information in commercial sheep flocks have been largely unidentified and underutilised. Traditionally, most genetic progress in commercial flocks has been derived from ram selection (Atkins *et al.* 2006) and few measurements have been made on ewes. The aim of this project is to produce tools to enable practitioners to identify ways in which maximum benefit can be achieved through more effective and efficient use of individual animal information in commercial sheep flocks. The tools will examine the potential use (and re-use) of production information (after hogget selection) for mate allocation, targeted management and culling decisions as well as the economic impact of these combinations. Much work has already been completed through the Cooperative Research Centre for Sheep Industry Innovation with precision sheep management (Atkins *et al.* 2006), which uses individual measurements to predict whole flock outcomes. However, the ability to predict production changes at an individual level has not been possible. This would enable a better understanding of the production and economic consequences of management and selection decisions on segments of the flock and the population as a whole.

Decision support tools have been used to predict the impact of current decisions on potential future decisions and the future production for whole flock changes over time (Kelly *et al.* 2006). They have highlighted the benefits of optimising flock structure to ensure optimal genetic progress as well as identifying selection options to achieve desired breeding objectives (Atkins *et al.* 2006). Ewe selection is often perceived to be of little benefit due to the low genetic gain it achieves. However, current generation gains from selection can be quite large (and profitable), with genetic progress an added advantage. Previous tools capture the overall benefit but cannot separate these into current and future gains.

Separating animals into similar management groups (according to their level of production or risk) can utilise the variation within flocks for both current and future generation gains. The immediate benefit of flock segmentation is easy to value. The difficulty is tracking the changes within these flocks over time. What do the progeny from these different groups look like? Will the progeny be retained in this group? What is the variation within groups? How many groups are required to best fit production constraints and market opportunities? Once the general potential changes and expected variation of flock segmentation is understood, various management and selection strategies within these groups will be investigated.

This will be a useful investigation for the whole industry as many resources are being allocated to developing new genetic, measurement and management technologies, but much less research is devoted to investigating the best ways of applying and combining this new information in the design and implementation of breeding and production programs, and how it might complement the strategies already adopted by industry.

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# Breeding to improve maternal efficiency and productivity in maternal sheep breeds

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**SUMMARY**

In the past decade producers have been rewarded by high prices for lamb. This has been driven by an increase in international demand for Australian lamb meat and a limited supply of lamb due to adverse seasonal conditions and decreasing sheep numbers (ABARE 2010). As lamb now makes a greater contribution to the profitability of sheep enterprises than wool, weight of lamb weaned and productivity of the ewe will become increasingly important (Wang and Dickerson 1991; Snowder and Fogarty 2009). In addition, Australia's sheep producing regions have experienced drought conditions for most of this period.

Ewes must cope with large variations in feed supply and remain productive for at least 4 years. During early lactation and feed shortages, ewes are in negative energy balance. The aim of this project is to quantify phenotypic and genetic relationships between the ewe's ability to maintain body condition (fat and muscle), wool production and maternal productivity. The primary hypothesis is that ewes with high estimated breeding values (EBVs) for fat depth (according to yearling ultrasound scanning) will be able to cope with variations in feed supply because of greater energy reserves.

The initial trial includes 2100 ewes from a maternal composite flock near Holbrook, New South Wales. Ewes will range from lambs, joined at 7 months, to 5-year-old ewes. Liveweight and body condition score will be measured at before joining, at joining, at the autumn lamb marking (about the end of the first trimester of gestation) and at weaning. The ewes will also be scanned for fat and muscle depth at weaning and autumn. These measures of ewe condition will be used to develop an understanding of the yearly fluctuation in body composition.

Analysis will take into account age, previous reproductive performance, weight of lamb weaned, lactation length and management group. The model will also fit a breed relationship matrix, breed dominance relationship and sire and animal effects. Young ewe EBVs associated with growth and body composition traits will also be accounted for as covariates.

The first trial will elucidate the importance of maternal efficiency on the ability of the ewe to wean a lamb and the role of fluctuations in body composition during the year. Additional data will be analysed to ensure sufficient variation in environmental conditions. We plan to analyse data from the Maternal Central Progeny Test and Information Nucleus Flock projects.

This study will provide the sheep industry with a better understanding of longevity of ewes, heritability of fluctuations in body composition, use of fat measurements to improve maternal performance, breed differences in maintenance of condition and maternal performance.

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# Is there an economic benefit in using mob-based walk-over weighing information for ewe management?

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**SUMMARY**

Ewe liveweight at joining affects the fecundity of Merino ewes (Oldham and Thompson 2004). Kelly and Croker (1990) reported an additional 1.1 lambs per 100 adult ewes per kg increase in ewe liveweight at mating. Condition score, which is correlated with liveweight (Frutos *et al*. 1997; Koycu *et al*. 2008), is also related to fecundity. These relationships suggest that monitoring of the average liveweight of a ewe flock may help producers to make more accurate decisions about feeding management and thus increase ewe productivity.

Mob-based walk-over weighing (MBWOW) is an emerging grazing management tool. It provides the producer with regular estimates of average liveweight and the distribution of liveweights in a mob of sheep. Prime lamb producers may be able to use such information to make better-informed decisions about the nutritional management of ewe mobs to increase fecundity. The aim of this experiment is to determine the economic benefits of using MBWOW technology to optimise grazing management decisions aimed at increasing the fecundity of pasture-fed ewes in a first-cross lamb production system.

The experiment will be replicated in three similar commercial prime lamb production systems for two production seasons and a control mob and a treatment (MBWOW) mob will be assessed in each production system. The hypothesis is that there is an economic benefit in using MBWOW as an aid to ewe management. The control mob will be subjected to grazing management decisions based on traditional paddock appraisal of the animals and pasture. The treatment mob will be subjected to grazing management decisions based on MBWOW data. Decisions will be made at two critical stages of the ewe production cycle: before joining and before lambing. In all cases, decisions will be made for the control flock before the MBWOW data is accessed.

Ewe fertility and fecundity and lambs weaned per hectare will be recorded for all mobs over 2 years. Input costs such as the cost of labour and supplementary feed will be recorded. This data will be incorporated into annual enterprise budgets and economic parameters for the two management systems. The economic benefit of MBWOW as an aid for ewe management in first-cross lamb production systems will then be quantified.

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# Can body condition score be used to refine worm control?

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**SUMMARY**

Anthelmintics are typically used to control worms and combat their deleterious effects on productivity, but inappropriate use has resulted in widespread resistance of worms to available anthelmintic treatment groups (Sutherland and Scott 2010). Adoption of new management strategies is required to slow the development of anthelmintic resistance. One potential strategy includes leaving a proportion of a flock untreated, which allows non-resistant (susceptible) worms to survive and thus slows the rate at which resistant genes accumulate in the worm population (Kenyon *et al.* 2009). The most appropriate indicator for selecting sheep that are to remain untreated is not clear. It is widely believed that sheep with a high body condition score (BCS) are better able to cope with worms (i.e., they have higher worm resilience) than sheep with low BCS, but little field research has been undertaken to verify this. Worm resilience is the ability to maintain an acceptable level of production despite a worm burden (Bisset *et al.* 2001). Figure 1 demonstrates a hypothetical relationship between BCS and worm egg counts (WECs) for worm resilient and non-resilient sheep.

The hypothesis of this project is that ewes with a low BCS will have greater production losses due to worms and will demonstrate a greater response to anthelmintic treatment than ewes with a high BCS. To test this hypothesis, Merino ewes at two properties have been allocated to groups with different BCSs but similar WECs. Half of the ewes in each group will receive regular anthelminitc treatment and half will remain untreated (Table 1). From May 2010 (pre-lambing) through to February 2011 (post-weaning), BCS, WEC and body weight assessments will be conducted to quantify responses to treatment (resilience).

**Figure 1.** Hypothetical relationship between BCS and worm resilience.

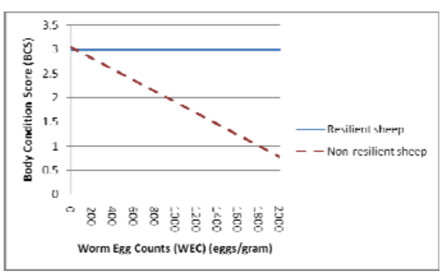


**Table 1.** Experimental design.

| | | |
|---|---|---|
| Merino Ewes 3 + years | BCS < 2.5 | Treated |
| | | Untreated |
| | BCS 2.5 | Treated |
| | | Untreated |
| | BCS 3.0 | Treated |
| | | Untreated |
| | BCS > 3.0 | Treated |
| | | Untreated |

Fieldwork commenced in May 2010 and collection of data is ongoing. Additional experiments will commence later in 2010 to determine the relationship between BCS and worm resilience across a range of flocks. This research will provide producers with practical strategies to delay the development of drench resistance. It also has the potential to improve productivity and reduce on-farm costs by targeting parasite treatments to the proportion of the flock that will derive the most benefit from the treatment.

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# Merino fibres with low cuticle step height and reduced surface roughness have a softer loose wool handle

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**SUMMARY**

Wool has little presence in the rapidly growing trans-seasonal, next-to-skin knitwear market, which is currently dominated by cotton and synthetic fibres. To be competitive in this market, it is necessary for wool garments to have an appealing, soft handle (softness). Resistance to compression (RtC) of loose wool is considered the best indicator of fibre softness and is significantly correlated with mean fibre diameter (MFD) and mean fibre curvature (MFC) (Madeley *et al.* 1998). Our previous work (Hillbrick and Huson 2008) showed that RtC and Young's modulus (tensile stiffness) were not significantly related, and for wool of similar diameter, Young's modulus was constant. We hypothesise that when the overwhelming effects of MFD and MFC are removed, fibre ellipticity, due to its effect on bending stiffness, and cuticle topography, because of its effect on fibre friction will be different for Merino wool samples that have different loose wool softness.

Two mid-side Merino samples, from the same flock, matched for MFD (15.8 μm) and MFC (64°/mm), with high (9 kPa) and low (7 kPa) RtC, were selected on the basis that their clean wool softness was significantly different. Raw wool staples from these samples were cleaned by gentle aqueous scouring. Fibre ellipticity and the coefficient of friction were measured on 20 randomly selected fibres from each scoured sample. Fibre ellipticity was determined from micrographs of fibre cross-sections. The coefficient of friction was measured in the with-scale ($\mu_{ws}$) and against-scale ($\mu_{as}$) directions using a capstan method. Cuticle step height, length and roughness measurements were made on 10 fibres from each sample using a scanning probe microscope (SPM) operated in Tapping-Mode™.

**Table 1. Secondary fibre characteristics for 15.8 μm MFD, 64°/mm MFC fibre with soft or harsh hand (mean ± 95% confidence interval)**

| Fibre characteristic | n | Soft hand (RtC 7 kPa) | Harsh hand (RtC 9 kPa) | *P*- value |
|---|---|---|---|---|
| Ellipticity | 20 | 1.16 ± 0.04 | 1.18 ± 0.04 | 0.59 |
| Coefficient of friction $\mu_{ws}$ | 20 | 0.27 ± 0.02 | 0.23 ± 0.02 | <0.001 |
| Coefficient of friction $\mu_{as}$ | 20 | 0.31 ± 0.02 | 0.28 ± 0.01 | <0.05 |
| Cuticle step height (nm) | 220 | 454 ± 23 | 598 ± 28 | <0.001 |
| Cuticle length (nm) | 165 | 9.7 ± 0.4 | 9.3 ± 0.4 | 0.09 |
| Cuticle roughness, rms (nm) | 25 | 6.8 ± 0.64 | 8.2 ± 1.1 | <0.05 |

Given that there were no differences in ellipticity (Table 1), and the assumption of equivalent Young's moduli (equal MFD), it seems unlikely that fibre bending stiffness plays a role in the differences in loose wool softness between these two Merino samples. The high coefficient of friction recorded for the softer sample is surprising and further investigation will be conducted using the capstan method as well as a SPM method. Fibres from the softer sample had a lower cuticle step height and a smoother surface. These are the most likely intrinsic fibre attributes, other than MFD and MFC, contributing to the softness of loose wool.

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# Worm egg count is not associated with greasy fleece weight in sheep phenotypically different for resistance or resilience to gastrointestinal nematodes

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**SUMMARY**

Promoting animals with increased immune response against gastrointestinal nematodes (worms) will have epidemiological benefits but may have deleterious consequences on production (Greer 2008). To investigate the effect of phenotypic resistance and resilience to worms on production characteristics in grazing sheep, a 2-year cross-over experiment was conducted.

On six farms, two mobs (yearling or mature age) of 300 or more Merino ewes were chosen at shearing in 2007. Within each mob, animals were randomly allocated to receive either normal management (challenged, $n$ = 60) or 'worm-free' treatment ($n$ = 60) involving suppressive control using combination long-acting anthelmintics. Faecal worm egg count (WEC) was measured individually every 2 months and greasy fleece weight (GFW) was measured at each shearing. Treatments were swapped at shearing in 2008 and continued until shearing 2009. Sheep were placed into quartiles based on either $WEC^{(1/3)}$ (resistance) or GFW (resilience) distributions within their treatment groups when challenged. The effect of resistance (WEC quartile) on challenged and worm-free GFW was analysed using an appropriate general linear model followed by Tukey's HSD test; the effect of resilience (GFW quartile) was analysed by intra-quartile comparison of GFW under worm-free and normal management.

**Table 1. The effect of worm resistance and resilience quartiles on greasy fleece weight (GFW) and worm egg count (back transformed, WEC) of grazing Merino ewes when challenged or worm-free**

| Resistance quartile[A] | WEC (epg) | GFW (kg) Challenged | GFW (kg) Worm-free | Resilience quartile[B] | WEC (epg) | GFW (kg) Challenged | GFW (kg) Worm-free |
|---|---|---|---|---|---|---|---|
| 1 | 208 | $3.33^{c}$ | $3.39^{bc}$ | 1 | 797 | 3.93 | 3.94 |
| 2 | 554 | $3.37^{c}$ | $3.51^{abc}$ | 2 | 759 | 3.53 | $3.70^{*}$ |
| 3 | 1040 | $3.34^{c}$ | $3.56^{ab}$ | 3 | 784 | 3.19 | $3.42^{*}$ |
| 4 | 2101 | $3.42^{bc}$ | $3.65^{a}$ | 4 | 761 | 2.82 | $3.12^{*}$ |

[A]Resistance quartile 1 is the most resistant (i.e., lowest WEC). Means with different letters differ significantly ($P$ < 0.05). [B]Resilience quartile 1 is the most resilient (i.e., highest GFW when challenged). [*]Significant difference between treatments ($P$ < 0.05). epg, eggs per gram.

More resistant sheep have a lower requirement for anthelmintic treatment but do not exhibit higher GFW in a challenged environment (Table 1). When worm-free, the most resistant quartile had a lower GFW than the most susceptible quartile. Increased resilience was not associated with higher WEC. Phenotypic selection for high fleece weight will not increase the need for anthelmintic treatment and improve resilience without adverse effects on worm control.

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# Trace metals in wool fibre increase the production of hydroxyl radicals and yellowing in photo-irradiated wool

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**SUMMARY**

The accepted mechanism responsible for photoyellowing of wool involves the production of hydroxyl radicals (Millington 2006). In biological systems, bound metals, particularly iron and copper, can catalyse the production of hydroxyl radicals, which damage proteins, lipids and carbohydrates (Stadtman 1990). We hypothesise that trace metals in wool influence hydroxyl radical production that occurs when wool is exposed to sunlight.

To investigate this, undyed wool fabric was doped with 0.2 mM copper and iron solutions. Hydroxyl radical production after exposure to UVA light (366 nm) was assayed by immersing fabrics in a solution of terephthalic acid (TA), which reacts specifically with hydroxyl radicals to form the fluorescent hydroxyterephthalic acid (HTA) ($\lambda_{ex}$ = 315 nm, $\lambda_{em}$ = 425 nm). The assay was repeated with the addition of deferoxamine mesylate (DEF), which chelates iron and copper, rendering them inactive as catalysts for hydroxyl radical production. Photoyellowing of fabrics was determined by measuring the yellowness (Y–Z) before and after irradiation with UVB light (280–320 nm), which induces levels of oxidation similar to that produced by prolonged exposure to UVA. Samples were irradiated while wet to increase the rate of photoyellowing and to enable the redox reactions that occur in metal-catalysed oxidation which require an aqueous medium.

The production of hydroxyl radicals increased significantly in iron-doped wool and increased marginally in copper-doped wool, whereas the addition of DEF to the TA solution decreased the production of hydroxyl radicals in all fabrics (Fig. 1). There was no difference between the initial yellowness of the fabrics (mean Y–Z = 8.6, s.d. = 0.7). However, after irradiation, copper-doped fabric was significantly yellower than untreated and iron-doped fabric (Y–Z was 16.0 for copper, 13.4 when untreated and 13.7 for iron).

The higher level of photoyellowing for copper-doped wool may be that copper binding sites on proteins are adjacent to high concentrations of tryptophan or tyrosine residues, which form yellow products in irradiated wool (Dyer *et al*. 2006) whereas photoyellowing catalysed by iron, which produces more hydroxyl radicals than copper, is far more random. The influence of intrinsic metals on the extent of damage and yellowing during exposure to light may only be important in the fibre tips, which receive the maximum dose of sunlight and have higher metal content than the remainder of the fibre.

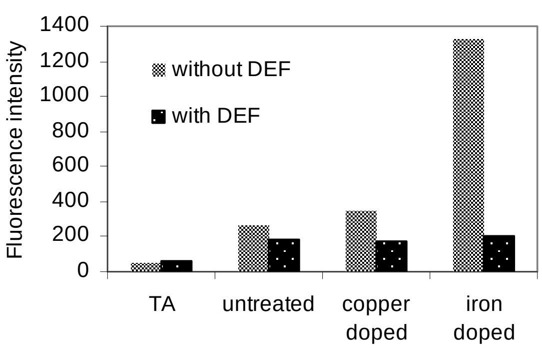


**Fig 1.** Fluorescence intensity at 425 nm of HTA, with and without DEF, after irradiation at 315 nm.

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# Investigation of eosinophil-specific galectin-14 as a genetic marker for resistance to *Haemonchus contortus*

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**SUMMARY**

Resistance to nematode infection has been shown to be immunologically mediated and associated with genetic background. Galectin-14 (gal-14) is an eosinophil-specific protein that has been identified as a mediator of parasitic infection (Dunphy *et al.* 2002). The aim of this study was to determine the relationship between gal-14 and worm burden in sheep and to assess its potential as a marker for nematode resistant sheep.

As part of a previous study, 30 eight-month-old Merinos wethers were treated for existing nematodes and randomly assigned into 2 treatment groups. One group was vaccinated with a larval antigen and adjuvant prior to a challenge with 2 × 5000 *Haemonchus contortus larval* antigen, which was administered orally. The control group only received the challenge. Abomasal mucus scrapings were collected and worm burdens were recorded. Mucus scrapings were analysed using Western blotting (Kemp *et al.* 2009). Nonparametric statistics were used to determine significance.

Our results showed that a greater number of sheep vaccinated against *H.contortus* released gal-14 into the mucus compared with unvaccinated sheep, suggesting that immunization increased tissue eosinophil recruitment. The positive relationship between gal-14 and worm burden in the vaccinated group suggests that gal-14 is not directly involved in immunity against adult worms but could be an indicator of worm burden. However, the relationship between gal-14 and larval worm burden remains to be investigated.

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# Producers have a positive attitude to behavioural change but are greatly influenced by enterprise factors and perceptions of control

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**SUMMARY**

Current lamb mortality rates pose serious productivity risks to Australian sheep producers already under threat from declining terms of trade and increased production costs (Productivity Commission, 2005). Practices such as the provision of shelter, focus-feeding, shearing prior to lambing and selection of ewes for calm temperament can reduce lamb mortality by up to 50% (Nowak and Poindron 2006). However, although producer knowledge of these practices and of various extension programs appears widespread, adoption tends to be limited (Logan 2005), suggesting that there is a need to identify factors influencing adoption.

Four focus groups were carried out with Western Australian sheep producers (n = 29) to investigate their beliefs and attitudes about lamb mortality and strategies to improve lamb survival rates. The Theory of Planned Behaviour (TPB; Ajzen, 1991) was used to guide the discussions and to code the data. The data were also coded for emergent themes.

Several key themes emerged from the focus group data. Producers had a positive attitude to change in response to lamb mortality. All of the producers thought that they could increase their productivity by improving lamb survival rates and were interested in potential solutions. However, although producers had a positive attitude to change, there was great variation in attitudes to individual strategies because of enterprise factors and perceptions of control.

Enterprise factors, such as goals and management structure, appeared to play an important role in decision-making. First, variation in attitudes to individual strategies tended to relate to how well the practice matched the goals of the primary enterprise. For example, 7 of the 18 superfine wool breeders implemented different strategies with their stud and commercial flocks. Second, enterprise factors may moderate the influence of attitudes on decision-making. For example, while it was widely agreed that it was vital to minimise disturbance and handling of sheep during lambing to reduce mortality, one producer felt that the demands of his enterprise required that he interact with the lambing flock to collect pedigree information.

Perceptions of control also appeared to play an important role in decision-making. Twelve producers stated that other aspects of the farming system, such as time constraints and labour and resource availability, prevented them from putting a particular practice in place.

In conclusion, sheep producers have a positive attitude to change in response to a perceived problem but have varying attitudes towards specific methods of addressing this problem. Additionally, enterprise factors and perceptions of control seem to play key roles in decision-making. A survey has been developed to confirm and quantify these relationships.

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# Sire and sire breed variation in neonatal lamb behaviour and vigour

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**SUMMARY**
Phenotypic variation in neonatal lamb vigour has been assessed in the Sheep Cooperative Research Centre's Information Nucleus Flock. Preliminary results indicate that sire breed variation in lamb vigour score exists and that vigour score is favourably correlated with lamb survival to 3 days of age (Brien *et al.* 2010). To understand this association further, a more detailed assessment of neonatal lamb behaviour, including a novel behaviour test for assessing vigour, was conducted in lambs from two sire breeds.

Thirty-seven twin- and triplet-bearing Merino ewes, pregnant to one of three Merino (M) or three Border Leicester (BL) sires lambed in individual pens. The ASBV for vigour score for each sire was known. Video records from birth to 3 h after birth were used to measure the time taken to stand and suckle for each lamb. A vigour score was also assigned to each lamb based on its behaviour until 3 h after birth. Lambs underwent a behavioural test (6–9 hours post partum) in which they were placed in an arena behind a wire mesh barrier and allowed 90 s to move past the barrier to a model of a ewe where an audio cue of a bleating ewe was played. Movement and overall responsiveness scores were recorded. Data were analysed using SAS PROC GLM and a nested model including the fixed effects, breed, sire nested within breed and litter size were fitted and birth weight was included as a covariate.

Overall score in the behaviour test was the only measure to differ significantly between sire breeds (2.8 ± 0.2 and 2.4 ± 0.2 for BL and M, respectively). Time to suckle and vigour score differed significantly between sires within breed (Fig. 1). Significant sire differences were also found for movement and overall responsiveness scores in the behaviour test (Fig. 1). Litter size had no effect on any behavioural trait. Moderately high correlations were found between vigour score ASBV and time to suckle (0.77) and vigour score (–0.68). Lower correlations were observed for movement and overall score (–0.28) during the behavioural test. This study confirms that there is phenotypic variation in neonatal lamb behaviour and vigour. Furthermore, there appears to be more variation due to sire within breed rather than to sire breed alone. These results also validate the utility of the field-based measure of lamb vigour.

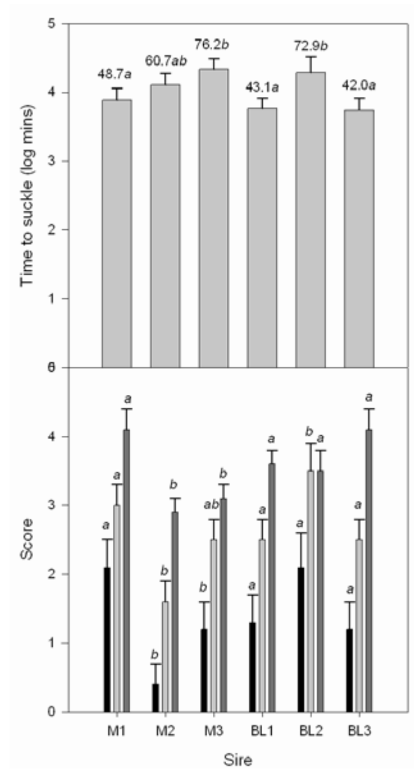


**Fig. 1.** Mean sire values for time to suckle (upper) and movement, overall responsiveness and vigour scores (black, light-grey and dark-grey bars, respectively, lower).

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# Glucose profiles may explain breed differences in cold resistance in the new born lamb

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**SUMMARY**

Cold resistance has been investigated as a predictor of a lamb's ability to withstand cold, as exposure is a major cause of neonate mortality. Slee *et al.* (1980) identified breed differences in the ability of lambs to endure cooling when immersed in a water bath. However, the physiological mechanisms responsible for differences in cold resistance have yet to be elucidated. We hypothesised that lambs resistant to cold stress are capable of maintaining heat generation by redirecting nutrients away from general metabolism towards thermogenesis. We present preliminary metabolic data for two genotypes differing in cold resistance.

Eighteen Merino and 22 Border Leicester lambs were investigated 24 h after birth. Lambs were placed in a water bath where the temperature was decreased from 36 °C to 15 °C over 1 h. The lamb was removed when core body temperature reached 35 °C, and the time taken to reach this temperature was termed cold resistance. Blood samples were collected before immersion and every 15 min whilst in the bath and were analysed for glucose level (Haemocue, Medipak Australia). Tidal volume and breath gas concentration were used to estimate $VCO_2$, and thus metabolic rate (Labchart, ADInstruments Australia) at 15 min intervals before and during the water bath. Results were analysed using ASReml and sex, type of birth, age of dam and breed were fitted as fixed effects and birth weight as covariate.

Cold resistance differed between the genotypes (Merino, 51 ± 2.1 min to reach 35 °C; Border Leicester, 55 ± 1.9 min to reach 35 °C). Genotypes also differed in plasma glucose concentration but not $VCO_2$ (Fig. 1).

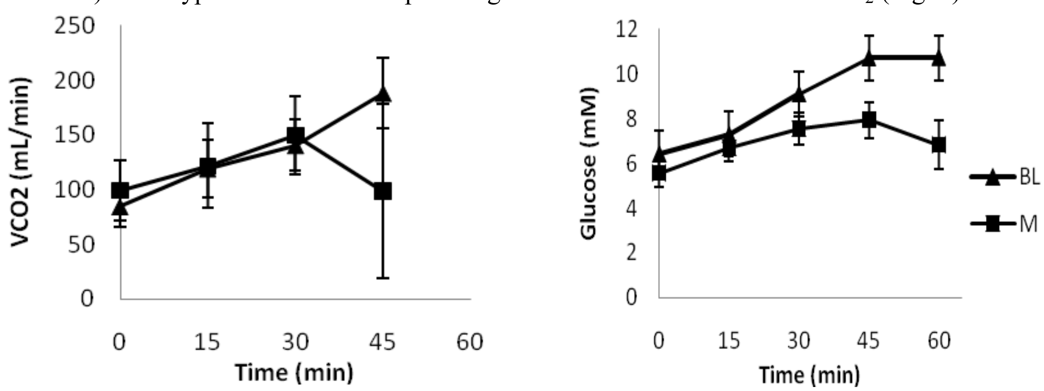


**Figure 1.** Change in $VCO_2$ (mL/min) and glucose concentration (mM) with time for Border Leicester (BL) and Merino (M) lambs immersed in a water bath that was cooled from 36 °C to 15 °C over 1 h. Values are presented as the least square mean ± SEM.

Although the design of the experiment was sensitive enough to distinguish variation in glucose between the two breeds, an increased number of animals may be required to detect a difference in metabolic rate. This, along with investigation of key metabolic hormones will be explored in future work.

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# GPS tracking: use of shelter and shade by Merino ewes

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**SUMMARY**

Information on the spatial distribution of ewes was obtained by deploying GPS collars on sheep on a commercial property on the Northern Tablelands of New South Wales. The aim of this study was to quantify the relationship between local weather, topography and use of shade and shelter by sheep in 2 paddocks of 20 ha. Paddock A was characterised by 3 distinct areas: “exterior shelter” consisting of perimeter shelter belts (3–4 rows of native trees), “lone trees” consisting of individual free-standing trees within the paddock, and “remainder of paddock”. Paddock B contained areas that were categorised as for paddock A, plus an “interior shelter”, a single, internal boomerang-shaped shelter belt. Over 2 lambing seasons (spring 2008 and 2009, 43–51 days), a random sample of 5 ewes from each of the 2 flocks of 200–300 ewes (2–5 years old and shorn 2 weeks prior to commencement of the experiment) were fitted with GPS collars set to log position every 10 min. Four weather stations and 55 temperature loggers were strategically located throughout the paddocks to provide localized hourly measurements of temperature, wind speed and precipitation over the observation periods. Daily temperatures ranged between –6 °C and 27 °C; nights were generally still and frost was common; days were often sunny and windy. Wind speed reached a mean maximum of 49.6 km/h. Strong westerly winds prevailed; northerly and southerly winds were unusual. The average rainfall during the observation period was 760 mm.

As the number of times that sheep were detected in the various paddock categories was similar in each year, data for the 2 years were combined. The percentage of observations in which sheep were within 25 m of each shelter class was determined during 3 key phases of the diurnal behavioural cycle: 19:00–04:00 (night camping); 05:00–11:00 (morning grazing) and 12:00–18:00 (afternoon grazing). During night camping and when an internal shelter belt was provided (Paddock B), sheep spent more time in the vicinity (0–25 m) of the interior shelter belt (56%) than free-standing trees (12%). In Paddock A, which contained only free-standing trees (43%) or perimeter shelter belts (40%), the difference between the times spent in these areas was not significant. During daylight, shade-seeking behaviour indicated an increase in the use of free-standing trees in both paddocks. Interior shelter or free-standing trees were utilised during night camping, which may have occurred because tree canopies reduce heat loss via radiation. During the day, shade reduces radiation load, which may be of more importance to sheep than the wind protection provided by the exterior shelter belts.

These results suggest that sheep prefer to manoeuvre in and around shelter and free-standing trees within a paddock rather than exterior shelter belts along fence lines. The effects of local weather temperature extremes, wind direction, altitude and diurnal movements on daytime and night-time preferences are currently being analysed.

# Lambing Merino ewes at 1 year of age – how productive and profitable for commercial enterprises?

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**SUMMARY**

The period of time from birth to reproduction in breeding females is non-productive and costly in sheep production systems (Emsen *et al*. 2005). Fogarty *et al*. (2007) suggested that joining ewe lambs in their first year may reduce the cost of ewe replacement by rapidly increasing the size of a breeding flock when replacement ewes are in short supply.

The Maternal Central Progeny Test demonstrated that, with optimal genetics and management, crossbred ewes can be successfully joined in autumn to lamb in their first year and have weaning rates of up to 90% (Fogarty *et al*. 2007). Joining of crossbred ewe lambs is now a common practice among Australian prime lamb producers. In contrast, joining of Merino ewes as lambs is rare and little information exists on the production potential or feasibility of such systems within commercial Merino flocks.

A prerequisite for joining Merino ewe lambs is oestrus activity in all or most ewes before 10–12 months of age (Hawker and Kennedy 1978). Watson and Gamble (1961) suggest that when Merino ewes are joined before 12 months of age, 60–80% may lamb provided that they are well grown and that joining is delayed until February or March.

This study will investigate the productivity of managing Merino ewes to lamb at between 12 and 15 months of age using 3 Merino bloodlines (Leahcim, Multi-Purpose Merino and Bundilla genotypes) across 3 geographically diverse locations. At weaning age, a random selection of ewes (n >50) will be obtained and managed in a 1-year-old lambing system on producer participant sites. Ewes in this system will be managed on pasture and supplements to achieve predetermined liveweight targets before joining, at joining, mid pregnancy and parturition and after weaning. Wool production, ewe pregnancy rate, lamb marking rate, lamb growth and weaning rate will be measured over 2 consecutive breeding seasons.

An economic analysis of the 1-year-old lambing system will be a major part of this study to test the hypothesis that under optimal management, Merino ewes can be lambed profitably at 12 months of age. Ewe liveweight targets will be modelled for a range of locations, soil types and pasture types in south-eastern Australia using Grassgro software to determine the requirements for additional pasture and supplementary feed of 1-year-old lambing systems. The profitability of 1-year-old lambing systems will be determined by comparing observed production levels and associated management costs with conventional 2-year-old lambing systems.

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# Merino ewes can be selected to lose less weight during periods of low nutrition

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**SUMMARY**

The weight of mature ewes in Mediterranean climates varies because of seasonal variation in the supply of pasture and affects farm profit. Ewes that lose more weight during the dry months of summer and autumn give birth to and raise less lambs (Kelly 1992) and require more supplementary feeding (Kopke *et al.* 2008). Despite the importance of weight change, the potential to breed ewes that lose less weight during summer and autumn has not been investigated. The aim of this study was to determine whether this trait is genetic.

Using a research dataset from Western Australia, we investigated change in weight from January to February (WJan–WFeb) and from May to October (WMay–WOct). Pedigree information and weight records from the Katanning base flocks for approximately 2700 adult ewes with on average 2 observations for both weight change traits were used (Greeff and Cox 2006). Variance components were estimated using ASReml. All weights were corrected for conceptus and greasy fleece weight.

The model included fixed effects of year (2000–2005), age (2–7 years) and number of lambs born and reared by each ewe in the year of weight measurement and in the year before the weight measurements (0–3). The first weight measurement from each trait, WJan for WJan–WFeb and WMay for WMay–WOct, and the total weight of lambs born in the year of weight measurement were fitted as covariates. Random effects were used to estimate additive genetic variance ($\sigma^2_a$), permanent environmental variance ($\sigma^2_{pe}$), maternal effect variance ($\sigma^2_{me}$, without pedigree information) and random residual variance ($\sigma^2_e$).

**Table 1. Means, minimums, maximums, variance components and heritability of weight change traits**

| Trait | Mean (kg ± s.d.) | Min. (kg) | Max. (kg) | $\sigma^2_a$ (± s.e.) | $\sigma^2_{ae}$ (± s.e.) | $\sigma^2_{me}$ (± s.e.) | $\sigma^2_e$ (± s.e.) | $h^2$ (± s.e.) |
|---|---|---|---|---|---|---|---|---|
| WJan–WFeb | 0.91 ± 5.04 | –17.4 | 17.6 | 2.58 ± 0.36 | 0.29 ± 0.39 | 0.20 ± 0.26 | 11.0 ± 0.30 | 0.18 ± 0.02 |
| WMay–WOct | –3.08 ± 7.98 | –36.2 | 24.5 | 7.20 ± 0.93 | 1.26 ± 0.92 | 0.81 ± 0.61 | 22.4 ± 0.62 | 0.23 ± 0.03 |

The phenotypic correlation (± s.e.) between WJan–WFeb and WMay–WOct was –0.39 ± 0.01 and the genotypic correlation was –0.05 ± 0.09. These correlations suggest that ewes that lose more weight between January and February gain more weight during May and October and vice versa. The relevance of these results will become clearer once the relationships between weight change during periods of low nutrition and reproduction and production traits are known. These results could perhaps be further improved by fitting curves to the weights using random regression. This would model variances and heritabilities of weight at any stage during the year as well as the correlations between weights at different times.

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