Genetic fat – bullet proofing the Merino ewe

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Introduction

Merino ewes are the backbone of the Australian sheep industry and this is likely to be the case for some time. Stocking rate will remain a key profit driver in Merino enterprises and to maintain or improve profitability producers will need to continually adapt their production systems to deal with even larger changes in feed supply between seasons and years. The reproductive performance of the Merino ewe also needs to improve, largely through improving the survival of twin born lambs, to rebuild flock numbers and meet market demand for lamb and sheep meat. Increasing both stocking rates and reproductive performance need to be achieved in the context of producers wanting to run more sheep per person with less intervention and increased consumer demand for welfare friendly products. Improving genetics and matching sheep genotype to the production and management system will inevitably become more important. We believe this will include defining traits to more easily identify Merino sheep that are more robust, that lose less liveweight when faced with sub-optimum nutrition and that produce more progeny with higher survival rates both pre- and post-weaning.

Increasing genetic fat is the prime candidate for increasing the robustness of Merino ewes and their progeny as the storage and mobilisation of fat is an important mechanism for all animals to cope with fluctuating environments. Fat is stored during favourable times and then mobilised to provide energy for fundamental functions when requirements exceed supply, such as during periods of limited nutrition or during late pregnancy and lactation. The amount of fat stored in fat depots in sheep can be increased by selection for higher subcutaneous fat depth, using Australian Sheep Breeding Values (ASBVs) from MERINOSELECT. However, from a genetic perspective, reducing the fatness of lamb to improve its appeal to the consumer has resulted in a general focus on selection for less fat in Australian sheep breeds. Merino sheep have also become leaner as a result of selection for higher fleece weights and the genetic association between higher fleece weight and reduced fatness (Huisman and Brown 2009). Defining the true value of fat requires an understanding of the effect it has on the value of lamb carcasses as well as its effects on the productivity of the sheep production system in different environments. In this paper we have reviewed published papers and our own unpublished work to test the hypothesis that Merino sheep that are genetically fatter will have improved performance especially under more restricted nutritional conditions.

Ewe liveweight loss to restricted nutrition

Sheep producers across southern Australia, especially those located in more marginal and variable environments, rank selection and breeding of sheep that are more resilient to poor nutrition and that can survive and produce under these conditions as a priority (M.B. Ferguson unpublished data). Data from the Sheep CRC Information Nucleus Flock indicate that ewes from some sires lost 5-kg of liveweight during summer and autumn when the supply and quality of paddock feed is limiting whereas ewes from other sires gained liveweight (John *et al.* 2011). Current estimates suggest that the heritability of this trait in Merinos is low (0.10-0.15; Rose *et al*. 2011), but nevertheless it could be possible to breed adult Merino ewes that are more tolerant to variations in feed supply. More information is needed on the genetic correlations between liveweight loss during summer and autumn and other production traits and the biological mechanisms responsible for differences in liveweight loss to determine the true value of the trait within different sheep production systems.

Ewes that lose less liveweight when paddock feed is limiting may be in better condition at mating and or throughout pregnancy resulting in higher fertility, fecundity and lamb survival. Rose *et al.* (2012) has shown that Merino ewes that lose less liveweight during mating on poor quality dry pasture have a higher probability of giving birth to and weaning lambs. The genetic correlations between liveweight change during mating and the probability of having a lamb ranged from 0.22 to 0.81 and the probability of weaning a lamb ranged from 0.56 to 0.93 across ewe age groups. It is known that liveweight loss during pregnancy also influences lamb birth weight and survival. Merino ewes that lose 10 kg during pregnancy produce lambs that are 0.3 to 0.5 kg lighter and this can reduce the survival of twin born lambs by up to 20% (Oldham *et al.* 2011). The risk of ewe mortality also increases rapidly below condition score 2 (A.N.Thompson unpublished data). It is therefore reasonable to expect that ewes which are genetically more robust and lose less weight during summer and autumn will wean more lambs, but the effect is likely to depend on time of mating and lambing in relation to seasonal changes in feed supply.

We have recently demonstrated that adult Merino ewes that lose less weight when nutrition is restricted are genetically fatter (S.E. John unpublished data). Ewes were fed rations formulated to achieve liveweight maintenance when offered *ad libitum* or an average liveweight loss of about 100 g/day when intake was restricted to 50% of estimated maintenance requirements. The results indicate a significant interaction between diet and estimated breeding values for yearling fat (YFAT, Fig. 1a). If nutrition was restricted, liveweight loss was reduced by about 25 g/day for every mm increase across the range of YFAT values (-1.28 to 1.01). By contrast, when fed around maintenance, albeit not statistically significant, weight gain was reduced by 19 g/day per mm increase in YFAT. Extrapolation of these data suggests that ewes with a 2-mm higher YFAT value could be up to 5-kg heavier if a restriction on nutrition similar to this study was imposed for 3 months. This association between liveweight loss and an easily measured trait like YFAT suggests that YFAT could potentially be used to select more robust Merino ewes.

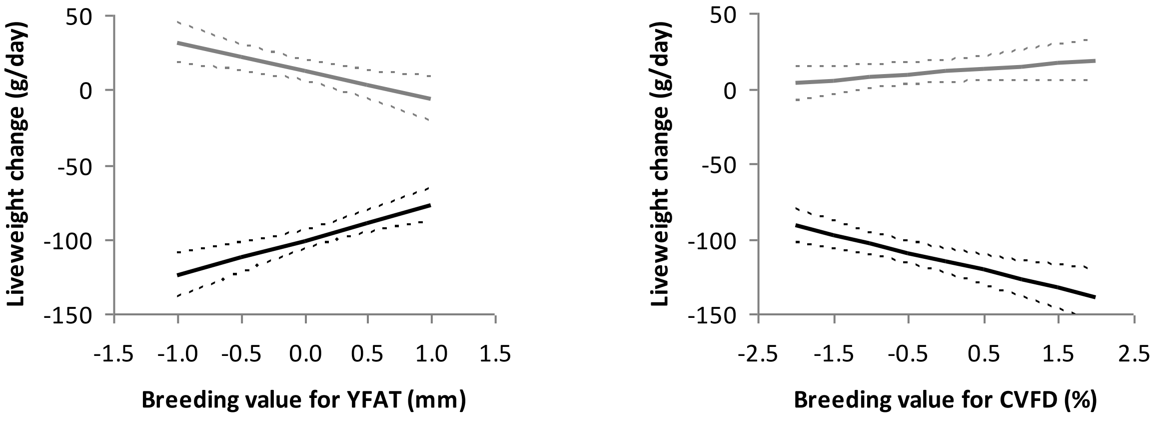

Figure 1. Effect of ewe breeding values for yearling fat (YFAT; a) or coefficient of variation of fibre diameter (CVFD; b) on liveweight change in adult Merino ewes fed a low quality diet either restricted to 50% of maintenance energy requirements (black) or *ad libitum* (grey) (S.E. John unpublished data).

The robustness of Merino ewes could also be influenced by selection for wool traits. Huisman and Brown (2009) have shown a negative genetic correlation between fleece weight and fatness. Based on Fig 1a, we therefore expected that sheep with high breeding values for fleece weight would lose more weight when fed the restricted diet but surprisingly the effect of breeding value for clean fleece weight on liveweight change was not significant for ewes fed either diet. It is also known genetic fatness is positively correlated with staple strength (Huisman and Brown 2009) and that high staple strength is associated with more uniform wool growth during the year which is indicative of greater resilience to variations in nutritional conditions. Sheep with a low ASBV for coefficient of variation in fibre diameter, are therefore expected to be genetically fatter, and will lose less weight when nutrition is restricted. This is consistent with Fig. 1b. There is clearly potential to influence the robustness of Merino ewes via selection for wool traits.

Ewe fertility, fecundity and number of lambs born

Fat plays an essential role in the reproductive process and sufficient fat reserves are necessary for animals to ovulate and successfully reproduce. This association has been demonstrated in sheep as a positive correlation between condition score at mating, fertility and fecundity. Selection for increased fatness should improve an animal's ability to reproduce, however the impact of ASBV for YFAT on number of lambs born is not straight forward. Ferguson *et al*. (2010) reported that Merino ewes with higher ASBVs for YFAT significantly increased the number of lambs born in two out of ten years; in some years there was virtually no impact of YFAT on ewe reproduction whereas in other years a 1-mm increase in YFAT resulted in 25 extra lambs born (Fig. 2). The effect of genetic fatness on the number of lambs born clearly varies between years and presumably is greatest when nutrition is more restricted prior to joining. Importantly, a preliminary analysis of almost 44,000 records from Merino ewes within the national MERINOSELECT database showed a positive correlation between YFAT and the number of lambs born of +18 lambs per 100 ewes per mm of YFAT (M.B. Ferguson, unpublished data). It is clear that on average there is a positive effect of YFAT on the number of lambs born but the magnitude of the effect varies over a wide range between years and presumably environments.

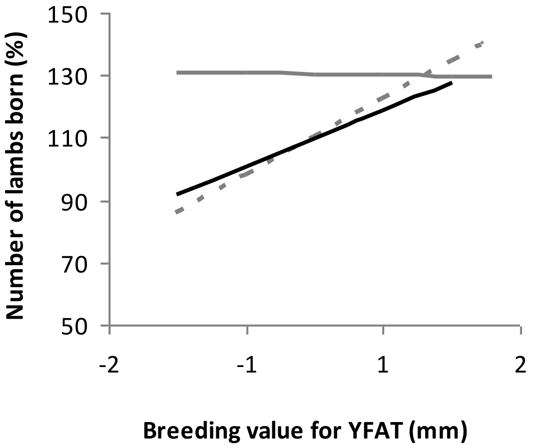

Figure 2. The effect of yearling fat depth (YFAT) ASBV of Merino ewes on the number of lambs born for different data sets; (a) Merinotech WA across two different years (grey; Ferguson *et al.* 2010); and (b) National MERINOSELECT database (black; M.B. Ferguson, unpublished data).

Lamb birth weight and survival

There are at least two ways that selection for increased fatness in Merinos could improve lamb birth weights and therefore lamb survival. Firstly, as indicated above, genetically fatter ewes would be expected to lose less weight and condition during pregnancy and produce bigger lambs. This would improve lamb survival given lamb birth weight is closely related to survival (Oldham *et al.* 2011). In support of this hypothesis, Vonnahme *et al.* (2006) reported that fetal weight was less impacted by restricted maternal nutrition in a desert adapted strain of sheep because they were better able to maintain condition score when nutrition was restricted than a non-adapted strain. Secondly, there is evidence that ewes that have proportionally more internal fat produced lambs of higher birth weight, and these effects of ewe fatness are more pronounced under poor nutrition than high nutrition and are independent of effects on ewe liveweight (Ferguson *et al*, submitted; Fig. 3). It is also possible that genetic fatness could influence lamb survival independent of these effects on lamb birth weight. It is well recognised that energy reserves at birth are critical for lamb survival, so it is reasonable to expect that selection for increased fatness of the dam, sire or both could be associated with greater energy reserves and therefore survival of the lamb independent of its birth weight. To test this hypothesis we have recently re-analysed lamb survival data from the Lifetimewool project reported by Oldham *et al.* (2011), taking into consideration the breeding values of the sires. As expected, birth weight was strongly correlated with the survival of lambs to weaning. At the same birth weight, single born lambs were more likely to survive than multiple born lambs and female lambs were more likely to survive than male lambs.

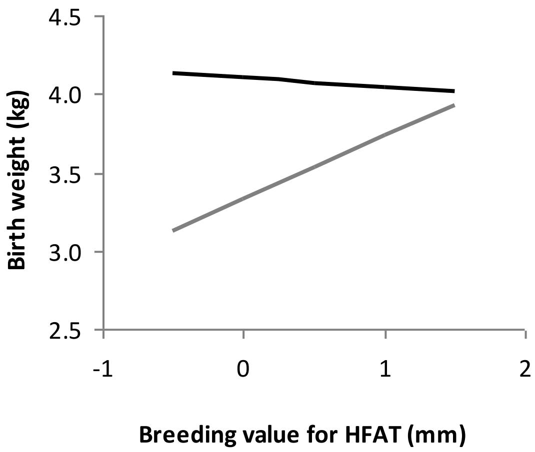

Figure 3. The effect of hogget fat depth (YFAT) ASBV of Merino ewes on lamb birth weight when ewes are managed on low (grey) or high (black) nutrition during pregnancy (Ferguson *et al.* submitted).

Analysis of data from the Lifetimewool project indicates that there were significant effects of the sire ASBVs for yearling weight, YFAT, and hogget clean fleece weight on lamb survival independent of their effects on birth weight. There was no interaction between sire ASBVs and birth rank of lamb, but there was a significant interaction between sire ASBV and sex of lamb such that the survival of the male lambs to weaning was influenced by the sire ASBVs for these traits but not the survival of the female lambs. The average survival of female lambs was similar to the survival of males from sires with the lowest yearling weight, highest YFAT (Fig. 4a) and lowest clean fleece weight (Fig 4b). In practical terms, the survival of 4-kg single male lambs from sires with a YFAT of +1 mm was similar to the survival rates as 5-kg single male lambs from sires with YFAT of - 1mm (80 *vs*. 81%). Similarly, 4 kg twin male lambs from sires with a YFAT of +1 mm had comparable survival rates to 4.5 kg twin lambs from sires with a YFAT of +1 mm (64 vs. 62%). At the same birth weight, lambs from sires with lowest yearling weight would be relatively more mature and the positive effects on lamb survival of high YFAT and low fleece weight could also be explained by proportional increases in the fatness of the lamb and hence its energy reserves. A recent analysis of more than 10,000 records from the Sheep CRC Information nucleus flock indicates a strong positive genetic correlation between HFAT and lamb survival across a range of sire and dam breeds (0.34 ± 0.053; David Rutley unpublished data). These findings, which collectively indicate that selection for increased fatness could improve lamb birth weights and lamb survival, will have implications for current selection strategies that directly or indirectly result in lower ewe fatness, especially in environments where shortfalls in nutrition during pregnancy frequently occur.

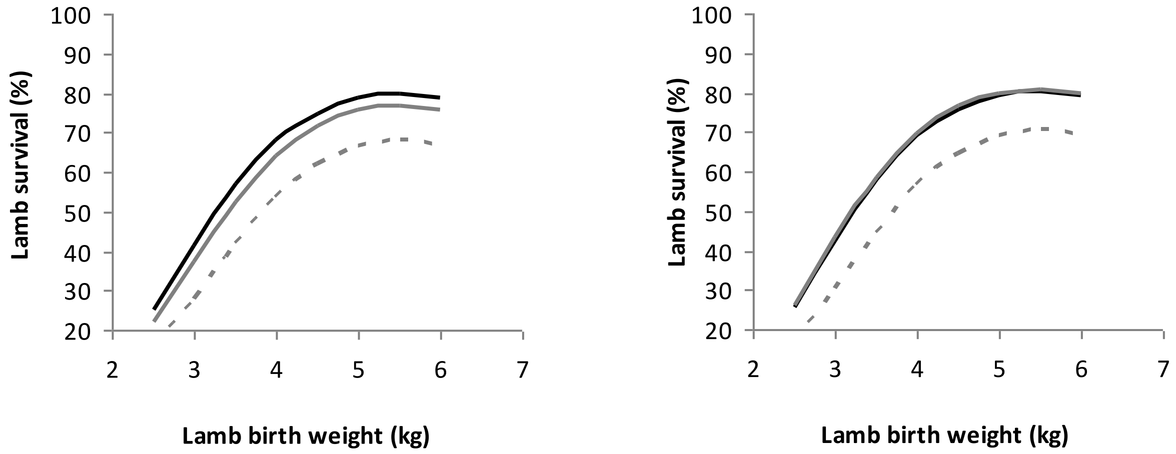

Figure 4. The relationship between birth weight and survival of twin lambs to weaning for: (a) Female lambs (black) or male lambs from sires with ASBV for yearling fat of +1 mm (grey) and -1 mm (dashed grey); and (b) Female lambs (black) or male lambs from sires with ASBV for hogget clean fleece weight of -10% (grey) and +20% (dashed grey). Data is from almost 1970 progeny from about 40 sires born in 2001 and 2002 at the Victorian site of the Lifetime Wool project (M.B. Ferguson unpublished data).

Weaning weight and weaner survival

Weaner survival is largely driven by weaning weight and post-weaning growth if growth rates are below about 50 g/day. Survival rates of weaners are very sensitive to liveweight when weaning weight are below 20 kg, whereas the changes in weaner survival from increasing weaning weights above 20 kg (or about 40% of mature weight) are much smaller (Thompson *et al.* 2011; Fig. 5). It is well recognised that lighter weaners are less able to cope with nutritional or other stresses due to smaller energy stores than heavier weaners. The survival of wether weaners is also less than the survival of ewe weaners. This effect of sex on weaner survival is not due to differences in weaning weight or post-weaning growth, but could be due to differences in body composition as wether weaners are often leaner than ewe weaners. The effects of lamb genotype on post-weaning survival remains largely unknown, but given these effects of weaning weight and sex on weaner survival, flock selection strategies which influence body composition could logically also influence weaner survival.

We hypothesise that selection for increased fatness of the dam, sire or both could be associated with greater energy reserves of the lamb at weaning and therefore increased post-weaning survival independent of weaning weight. To test this hypothesis we have recently re-analysed weaner survival data from the Lifetimewool project reported by Thompson *et al.* (2011), taking into consideration the breeding values of the sires. There were significant effects of the sire ASBVs for YFAT (Fig. 5a), yearling eye muscle depth, hogget clean fleece weight (Fig. 5b) and the coefficient of variation of fibre diameter on weaner survival independent of their effects on weaning weight. Unlike the effects on lamb survival, there was no significant interaction between sire ASBV and sex and the effects of lamb genotype were similar for both ewes and wethers. The average survival of ewe weaners was significantly greater than the survival of wether weaners and the survival was greater for weaners from sires with higher fat and muscle and lower clean fleece weight and coefficient of variation of fibre diameter. In practical terms, 15 kg weaners from sires with a YFAT of 1 mm achieved similar survival rates as 20-kg weaners from sires with YFAT of - 1mm (92.8 *vs*. 92.1%). Most importantly, the effects of sire breeding values on weaner survival were much greater at low weaning weights, which are more typical of late lambing flocks, high stocking rate farms or poor seasons. These findings indicate that selection for increased fatness could improve both lamb and weaner survival especially when conditions are tough resulting in low weaning weights. Furthermore, the effects of selection for increased fatness on lamb and weaner survival could be greater than indicated by our preliminary analysis given we have only considered sire effects.

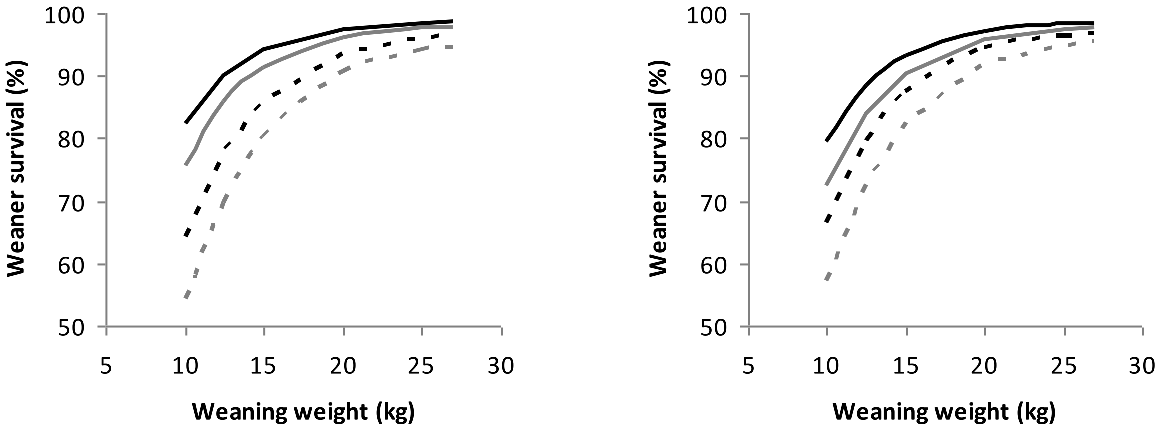

Figure 5. The relationship between weaning weight and survival until 12 months of age for ewe (black) or wether lambs (grey) from: (a) sires with ASBVs for yearling fat of + 1 mm (solid) and - 1 mm (dashed); and (b) sires with ASBVs for hogget clean fleece weight of -10% (solid) and +20% (dashed). Data is from almost 1340 progeny from about 40 sires born in 2001 and 2002 at the Victorian site of the Lifetime Wool project (A.N. Thompson unpublished data).

Economic value of genetic fat and conclusions

In this paper we have described how selecting to increase fatness in Merinos could potentially improve their robustness to feed deficits by reducing their liveweight loss during summer and autumn, increasing the number of lambs born and improving both lamb and weaner survival. Estimating the economic benefits of these changes is complex. We have previously reported how the positive effect of YFAT on the number of lambs born can influence farm profit in some years, taking into consideration that the effects of YFAT on GR fat depth was not significantly strong to change carcass value (Ferguson *et al.* 2010). We have also reported that ewes that lose less weight when there is a shortage of paddock feed are potentially more profitable than ewes that lose more weight because they may require less supplementary feeding or could be grazed at higher stocking rates during autumn/winter (Young *et al*. 2011). The table below summarises the possible value of each of the components that have been discussed in this paper with values being drawn from published and unpublished economic analyses.

Table 1. The effects of production responses to genetic fatness in Merino sheep on potential economic benefits.

	Production response to FAT		Economic benefit	
	-1 mm	+ 1 mm	$/unit of trait/ewe	$/ewe
Liveweight loss (kg) [1]	- 11.2	-7	$8,800/1 kg/3800 ewes[4]	$9.70
Number of lambs born (%)[2]	91	128	$13,080/24.5% NLB/4200 ewes[5]	$4.70
Lamb survival – singles (%)[3]	81	87	$0.43/%/ewe x 50%[6]	$1.29
– twins (%)[3]	53	64	$0.29/%/ewe x 50%[6]	$1.59
Weaner survival (%)	88	95	$0.96/%/ewe[6]	$6.70
Total				**$23.82**

[1] approx -25g/day per mm YFAT x 3 months (Fig 1a); [2] average response from SG data (Fig 2); [3] males only (Fig 4a); [4] from Young *et al*. (2011); [5] from Ferguson *et al*. (2010); [6] from J.M. Young unpublished.

The total potential value of moving from FAT from -1 mm to +1 mm could be in excess of $20/ewe, or more than $70,000 per farm for a typical farm with a breeding flock of 3000 ewes, but this estimate does not include the cost of any adverse movement of traits correlated with fatness such as clean fleece weight. Care is required in determining the appropriate selection pressure to be placed on genetic fatness in Merino selection until a more complete economic analysis is completed when the production responses to increasing genetic fatness in Merinos are fully understood. However, it is highly likely that genetic fatness in Merino sheep could be far more important than previously considered.

References

John SE, Ferguson MB, Gardner GE, Thompson AN (2011) Fluctuation in ewe liveweight during periods of restricted nutrition is influenced by sire**. 19th** *Proc. Ass. Adv. An. Breed. Gen.* 450-453.

Ferguson MB, Young JM, Kearney G, Gardiner GE, Robertson IRD, Thompson AN (2010) The value of fatness in Merinos ewes differs with production environment. *Anim Prod Sci* 51; 866-872.

Huisman AE, Brown DJ (2009) Genetic parameters for bodyweight, wool, and disease resistance and reproduction traits in Merino sheep.3. Genetic relationships between ultrasound scan traits and other traits. *Anim Prod Sci,* 49, 283–288

Oldham CM, Thompson AN, Ferguson MB, Gordon DJ, Kearney GA, Paganoni BL (2011) The birth weight and survival of Merino lambs can be predicted from the liveweight profile of their mothers during pregnancy. *Anim Prod Sci* 51; 776-783.

Rose G, Mulder HA, van der Werf JHJ, Thompson AN, Ferguson MB, van Arendonk JAM (2012) Genetically, Merino ewes that lose less weight during joining have a higher chance of having lambs but the total weight of the lambs is not effected. *Anim Prod Sci (submitted)*

Rose G, Kause A, Mulder HA, van der Werf JHJ, Thompson AN, Ferguson MB, van Arendonk JAM (2012) Adult Merino ewes can be bred for live weight change to be more tolerant to uncertain feed supply. *J Anim Sci (submitted)*

Thompson AN, Ferguson MB, Campbell A, Gordon DJ, Kearney GA, Oldham CM, Paganoni BL (2011) Improving the nutrition of Merino ewes during pregnancy and lactation increases weaning weight and survival of progeny but does not affect their mature size. *Anim Prod Sci* 51; 784-793.

Vonnahme K A, Hess BW, Nijland NJ, Nathanielsz PW, Ford SP (2006) Placentomal differentiation may compensate for maternal nutrient restriction in ewes adapted to harsh range conditions. *J. Anim. Sci*. 84:3451–3459.

Young J.M., Ferguson M.B. and Thompson A.N. (2011) The potential value of genetic differences in liveweight loss during summer and autumn in Merinos ewes differs with production environment. **19th** *Proc. Ass. Adv. An. Breed. Gen.* 307-310.