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Nutrition and Lean Meat Yield (LMY) project

The effects of ewe gestational condition, genetic potential for lean meat yield and finishing nutrition on the body composition, lean meat yield and meat quality of male second cross prime lambs

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Abstract

The prime lamb industry is seeking to increase lean meat yield (LMY) whilst maintaining meat eating quality. This project investigated the impact of gestational condition score, sire breeding values for LMY and finishing diet on the body composition, lean meat yield and eating quality of prime lambs. Adult maternal ewes were artificially inseminated to 9 sires selected on research breeding values for high, medium and low LMY. Subsequently, 648 pregnant ewes were randomly allocated and managed towards three different condition score (CS) targets of 2.5, 3.0 and 3.5 at lambing. Ewes at lambing were different by an average of 0.7 CS and 13kg liveweight between the CS2.5 and CS3.5 treatments. There were very few significant interactions between CS treatment, finishing diet and sire group. The CS 2.5 treatment resulted in lower birth, marking, weaning, finishing, pre-slaughter and carcass weight in multiple lambs. These lambs were also chemically leaner (by approximately 1% unit) than lambs born to CS 3.0 and CS 3.5 treatments. The difference in fatness appeared to be due to differences inter-muscular fat (and possibly intra-muscular fat). However, there were no significant differences in lean meat yield measured by either partial or full bone out. The finishing diet affected growth rate, food conversion ratio and pre-slaughter weight but not leanness or fatness. Progeny from high LMY sires were leaner, with less subcutaneous and intramuscular fat and had a high shear force. The results indicate producers will gain more from improved CS management for lamb survival and weight benefits and this may also result in improvements in fresh and retail meat colour.

Executive summary

The lamb industry has increased focus on improving Lean Meat Yield (LMY) while maintaining or improving meat eating quality. If successful, this will increase the overall efficiency and profitability of the industry. However, Sheep CRC research has shown that although LMY is heritable trait, it has a negative genetic correlation with intramuscular fat content (IMF) and meat tenderness (measured by shear force). Both IMF and tenderness are important for eating quality and acceptance by consumers.

Past research has also shown that severe under-nutrition of the ewe during pregnancy can lead to progeny that have lower birth weight with a higher proportion body fat. However, little is known about the interaction of sheep genetically selected for LMY and meat quality with the level of ewe nutrition during pregnancy.

This experiment was conducted to increase understanding of the effects of maternal ewe nutrition during pregnancy on body composition and productivity of prime lambs with differing genetic potentials for LMY when they were finished in an intensive feedlot system. Ewes were artificially inseminated to sires selected on research breeding values for high, medium and low LMY. The pregnant ewes were randomly allocated and managed towards three different condition score (CS) targets of 2.5, 3.0 and 3.5 at lambing

The key findings were:

- Lambs born to the low CS2.5 treatment weighed 230 grams less than lambs born from CS3.0 treatment ewes at birth. This difference weight were maintained throughout life and particularly evident for multiple born lambs.
- Ewe under-nutrition through pregnancy did not increase the IMF content of the CS 2.5 treatment lambs, contrary to published data.
- Lambs born under CS 2.5 treatment also had lower fresh and retail colour.
- Progeny from Sires selected for high LMY research breeding values resulted in carcasses that were leaner with both lower inter and intra muscular fat resulting in higher shear force (increased toughness).

For producers this means despite a possible increase in LMY in progeny produced from ewes with lower nutrition during pregnancy, the negative impacts on liveweight, hot carcass weight and meat colour, would override the potential LMY gains. Furthermore lower CS at lambing could lead to lower lamb survival.

On farm management strategies should therefore aim to increase CS during pregnancy for multiple bearing ewes so that these ewes are higher than CS 3 at lambing, in order to improve survival, weaning weight and safeguard meat quality. The gains in weaning percentage and carcass weight found in this experiment would more than outweigh reduced LMY of a low CS treatment, resulting in around 2 tonnes of extra lean lamb per 1000 ewes joined.

This study has also highlighted issues that require further research. These include investigation of the causative mechanisms for the changes in meat colour that occurred due to condition score treatments; development of feedlot finishing systems that can improve retail colour stability and IMF content, and the development of optimum condition score profiles for maternal ewes. Confirmation is required on the impact of CS management effects observed in this study on lamb survival in maternal ewes for both single and multiple bearing ewes.

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1. Background

The efficient production of lamb that is consistent in quality and value is important for sheep meat industries to remain competitive (Pethick *et al.* 2006). Improving the amount of saleable meat from lambs within production systems is a key component to increasing the value of lambs within the supply chain. This can be achieved by improving dressing percentage (the proportion of the animal that is carcass) and through increasing lean meat yield (a function of the weight of muscle relative to the weight of the carcass; Jones *et al.* 2002). Strong genetic correlations have been found between the direct selection for lean meat yield and reduction in intramuscular fat content and increased meat toughness in lamb (Mortimer *et al.* 2010, Mortimer *et al.* 2014). Hence, direct selection of sires for lean meat yield may negatively impact on lamb eating quality. In work published by Hopkins *et al.* (2005), increasing sire Australian Standard Breeding Values (ASBVs) for muscling was associated with negative impacts meat eating quality in the progeny. This impact was postulated to be due in part to a reduction in intramuscular fat (IMF) content, an observation supported by Thompson *et al.* (2007).

The impact of nutrition in the ewe before joining or during pregnancy and lactation is known to have effects on ewe reproduction (Robinson *et al.* 2006, Ferguson *et al.* 2011) productivity (Masters *et al.* 1993, Ferguson *et al.* 2011) and lamb birth weights and survival (Knight *et al.* 1988, Oldham *et al.* 2011, Behrendt *et al.* 2011). Ewe nutrition during key periods of development in utero and pre-weaning can also have permanent impacts on the production potential of the progeny (reviewed by Bell 2006; Greenwood *et al.* 2010). Greenwood and Bell (2003) showed that the postnatal consequences of intra-uterine growth retardation in sheep were hypoglycaemia and sluggish postnatal engagement of the growth hormone (GH)-insulin-like growth factor (IGF) system. When lambs are reared in an optimum environment, low birth weight lambs grow at rates similar to those of normal lambs (Greenwood *et al.* 1998). However, low birth weight lambs are fatter at any given weight (up to 20kg), have high energy intakes, but lower maintenance energy requirements and limited capacity for bone and muscle growth. Both birth weight and growth rate have significant effects on organ weights and growth rate of organs (Greenwood *et al.* 2004). These observations suggest that intra-uterine growth retardation may directly influence lean meat yield and dressing percentage in lambs at slaughter.

Research conducted within the Lifetime Wool program (www.lifetimewool.com.au; Thompson 2011) also investigated the influence of variation in the live weight profile of the Merino ewe on her performance (wool production and reproduction) and the impacts of her nutrition on the lifetime performance of her progeny (survival, growth to weaning and wool production). This resulted in the development of guidelines for the management of Merino ewes for optimum lifetime performance and productivity of their offspring for wool production (Young *et al.* 2011). The guidelines developed by the Lifetime Wool program can be used to inform aspects of reproduction, survival and growth to weaning in non-Merino breeds, however, this knowledge is limited in its application outside of Merinos, by the greater number of multiple births, maternal nature, propensity for growth, fat and muscle and range in body composition of maternal composite and terminal lamb breeds.

The release of research breeding values for lean meat yield also allows the variation in sire genetics for aspects of carcase value/meat quality to be examined in combination with the influence of nutritional restriction of the ewe in such experiments. To date, there is little published knowledge regarding the interaction of genetic range for high value carcase, meat quality and lamb survival traits with ewe, weaner and finishing system nutritional and management interventions. This limits our knowledge of the influence of change in genetic capacity for these high-value traits within different production systems on whole farm productivity, efficiency, economic and risk reduction benefits. Improved understanding of the interaction between ewe gestational nutrition, sire genotype and the feed-base are required to improve the productivity (including survival and production) and quality (slaughter lambs that meet specifications and eating quality of these) of lambs produced.

The aim of this was experiment to develop an understanding of the interactions between ewe gestational condition, genetic potential of the lamb for body composition and varying lamb finishing systems on the body composition of male lamb progeny and their subsequent lean meat yield, dressing percentage and meat quality. The outcomes will lead to management strategies to improve productivity (growth rate) and value (lean meat yield, dressing percentage and meat quality) in self-replacing and terminal lamb production systems.

2. Project objectives

To address research knowledge gaps in;

1. The effect of gestational condition change in the last trimester in crossbred and maternal composite ewes on lamb growth, change in body composition during finishing, LMY, meat quality and the link between LMY and intramuscular fat content (IMF).

2. The effect of variation in protein and energy ratios in finishing diets on final body composition (fat, muscle and bone), carcase and meat quality and the link between LMY and IMF content in wether slaughter lamb progeny in terminal lamb production systems.

3. The effect of variation in protein and energy ratios in finishing diets to modify the influence of ewe gestational condition score on body composition (fat, muscle and bone), carcase and meat quality and the link between LMY and IMF content in wether slaughter lamb progeny in terminal lamb production systems

4. The interaction between ewe gestational condition with sire genetic potential for LMY and IMF on the deposition of fat, muscle and bone during finishing of wether slaughter lamb progeny and subsequent carcase and meat quality attributes in terminal lamb production systems.

5. The interaction between variation in protein and energy ratios in finishing diets with sire genetic potential for LMY and IMF on the deposition of fat, muscle and bone during finishing of wether slaughter lamb progeny and subsequent carcase and meat quality attributes in terminal lamb production systems.

6. The interactions between ewe gestational condition, variation in protein and energy ratios in finishing diets and sire genetic potential for LMY and IMF on the deposition of fat, muscle and bone during finishing of wether slaughter lamb progeny and subsequent carcase and meat quality attributes in terminal lamb production systems.

3. Methodology

Overview

The project involved artificial insemination (AI) of 938 (1st Cross Merino x Border Leicester and Maternal / Coopworth Composite) ewes to 9 sires with the aim of producing at least 72 pregnant ewes from each sire. These 648 (9 × 72) ewes, their male and female progeny to weaning, and their male progeny to slaughter were the experimental material for this research. The core of the design was based on 3 condition score (CS) / ewe liveweight change / nutritional treatments during gestation that were aimed at having ewes reach CS 2.5, CS 3.0 and CS 3.5 by lambing (from CS 3.0 at AI and pregnancy scanning). The CS/liveweight/nutritional treatment was applied to 6 replicates (6 cells of 36 ewes in each of 3 blocks) with 9 sires selected on the basis of lean meat yield. The 938 ewes artificially inseminated were selected to be within similar ranges of CS and liveweight such that heavy or light or fat and thin ewes were not included in the study. The condition score of the 938 ewes was managed to a flock average of CS 3.0 prior to artificial insemination and ewes were maintained at a flock average of CS 3.0 until ultrasound scanning to confirm pregnancy and number of foetuses. Following pregnancy scanning, 648 ewes were randomly allocated amongst 18 management groups early in the second trimester of gestation. As the gestational CS treatment and mating of sires is applied to ewes, and to keep within the experimental design paradigm for maximum cause and effect, all allocations were applied to a ewe and her male progeny.

The 18 ewe management groups were allocated to the former Hamilton EverGraze site (www.evergraze.com.au) and measures of pasture feed on offer, botanical composition and nutritive value were undertaken. Nutrition was managed by the allocation of feed-on-offer (kg dry matter (DM)/ha) and some supplementation during the last 2 trimesters to achieve proposed condition score targets at lambing. Ewes were grazed in a 3 paddock rotation and the length of grazing was different between CS treatment groups, blocks and replicates with primary aim of supplying the appropriate nutrition to achieve the CS and liveweight change needed to meet the target CS at lambing. Ewes were regularly measured for CS, liveweight and also ultrasound scanned for muscle and fat depth on four occasions. Ewes were lambed within their assigned experimental replicate with single bearing ewes lambed in open paddocks and twin bearing ewes lambed in an allocated tall wheatgrass hedgerow plot (see www.evergraze.com.au for further information). Data regarding ewe and lamb identification, birth weight and birth type were recorded at lambing. Single and twin lambing ewes in each replicate were re-aggregated after the completion of lambing prior to lamb marking at which point they were again rotationally grazed until weaning. The restrictions due to nutritional treatment on feed-on-offer were removed at lambing and ewes and lambs were given full access to the available supply of pasture until weaning. All lambs were weaned at 12 weeks of age, weighed and ultrasound scanned for muscle and fat depth. The female progeny were returned to the DEPI commercial farm for management, while the male progeny were retained in the experiment and backgrounded at pasture in their three AI groups/blocks until feedlot induction. The lambs achieved a low rate of liveweight gain with supplementary feeding of barley during backgrounding due to very dry seasonal conditions.

Male lambs entered the feedlot in stages consistent with the three AI groups/blocks. Each group of lambs went through a feedlot induction phase with *ad libitum* Lucerne hay and increasing supply of the pellet ration over a 10 day period, after which *ad libitum* access to the pellets was offered together with access to barley straw. The males received three different feedlot rations containing different levels of metabolisable energy (ME) and crude protein (CP). The three rations were;

- High Energy, High Protein – tested at 13.2MJ ME/kgDM and 24.2% CP;
- High Energy, Moderate protein – tested at 13.0MJ ME/kgDM and 19.2% CP;
- Moderate Energy, High protein – tested at 11.0MJ ME/kgDM and 23.7% CP.

The GrazFeed predicted weight gain for prime lambs (35kg) based on the nutritive value of these rations as given above was 353, 344 and 202g/day respectively.

Lambs were slaughtered sequentially in April and May 2013 on three slaughter dates consistent with the three AI groups/blocks, such that all treatments were represented at each slaughter. Carcass weight, dressing percentage, fat and muscle depths and fresh meat colour were record in the abattoir. A half-carcass from each lamb was cut into primals and transported to DEPI Hamilton where each carcass was subjected to Dual X-Ray absorptiometry (DXA) prior to either full or partial dissection to determine lean meat yield. Samples were also collected for analysis of shear force, intramuscular fat (IMF) and retail colour.

Sire Selection

Semen from 9 sires representing proven meat breeds (e.g. Poll Dorset, White Suffolk) were obtained to provide a range in Lean Meat Yield (LMY) breeding values whilst as far as possible maintaining similar levels for all other Australian Sheep Breeding Values (ASBV) for the major production traits. The ASBV and Research Breeding Values (RBV) for each sire are presented in Table 1 below. The sires were grouped according to their values for LMY as either Low, Moderate or High. Table 1 indicates the block of ewes to which each sire was applied in the experiment.

Artificial insemination and pregnancy scanning

A total of 938 ewes were artificially inseminated (AI) to 9 sires in 3 separate groups (blocks) on the 19thand 20th April, 26th and 27th April respectively. Pregnancy scanning occurred on the 7th of June at 43 to 49 days after AI. The conception rate over all ewes was 78.6% of all ewes prepared for AI or 80.7% for ewes that were artificially inseminated. 19.3% of the artificially inseminated ewes were dry with the average reproductive rate 128% (including dry ewes). The first cross ewes scanned 21% dry and 122% fetuses per ewe artificially inseminated compared to 17.5% dry and 135% for the maternal composite ewes. Removing dry sheep the average reproductive rate for first cross ewes was 154% and 164% for the maternal composites. A total of 1202 lambs were expected from all ewes/fetuses scanned.

Experimental allocation

Following pregnancy scanning ewes were allocated randomly within their AI groups/blocks to three condition score treatments with 2 replicates per treatment to produce a total of 18 management groups each containing 36 ewes (Figure 1).

The average reproductive rate of ewes allocated to each experimental replicate was 156 % comprising 44.3% singles and 55.6% twin bearing ewes per plot. One triplet bearing ewe was also allocated to balance ewes to sires. This allocation would result in the birth of on average of 28.4% single and 71.3% twin lambs across the experiment with 1010 lambs expected at birth.

At lambing twin bearing ewes were lambed in Tall Wheatgrass hedgerow plots that offer improved shelter and lamb survival, whilst single bearing ewes were lambed in the open paddocks of the former Hamilton EverGraze site (www.evergraze.com.au). All allocations maintained the integrity the design structure.

Following weaning male lambs were backgrounded at pasture in their AI group/block prior to entering the induction and then feedlot finishing phase at which point lambs were allocated to receive one of three diets during the finishing period according to the design shown in Figure 2. This allocation created 9 feedlot pens. Lambs were then slaughtered at the end of finishing sequentially with all pens in a particular block being slaughtered on the same kill date.

Table 1. Australian Sheep Breeding Values (ASBV) and Research Breeding Values (RBV) for sires selected for artificial insemination (AI) to ewes in each AI block and lean meat yield (LMY) sire group.

			ASBVs												
LMY Sire Group	**Block**	**SIRE**	**BWT**	**WWT**	**PWT**	**AWT**	**WFAT**	**PFAT**	**WEMD**	**PEMD**	**PWEC**	**PSC**	**NLB**	**NLW**	**MWWT**
Low	1	WARATAH-090577	0.4	10.2	16.0	17.4	-0.6	-0.7	0.4	0.6	-7.0	4.7	0.1	0.1	2.0
Low	2	PENDARRA-075630	0.0	8.2	13.7	14.4	0.1	-0.1	1.7	2.0	35.0	3.3	0.0	0.0	1.5
Low	3	PENDARRA-096981	0.2	6.4	9.8	11.2	-1.2	-1.4	-0.5	-0.6		2.3	0.0	0.0	3.7
Mod	1	WARATAH-110138	0.5	9.2	14.8	17.4	-0.2	-0.4	0.8	1.2	-35.0	3.8	0.0	0.0	3.4
Mod	2	WOOLUMBOOL-105317	0.4	7.7	12.0	15.7	-0.2	-0.1	1.5	1.6	-53.0	3.3	0.1	0.1	2.3
Mod	3	LINTON-070644	0.5	10.3	15.3	18.9	-0.3	-0.6	0.7	0.6	4.0	2.4	-0.2	-0.2	1.8
High	1	WUNNAMURRA-110173	0.4	10.5	15.1	18.9	-0.3	-0.3	1.3	1.6					2.5
High	2	MAJARDAH-090617	0.2	7.8	11.7	14.8	0.0	-0.2	2.8	3.3	-47.0	2.6	-0.1	0.0	2.6
High	3	VALMA-060349	0.4	9.7	15.3	21.7	-1.3	-2.1	0.3	0.7	-35.0	4.0	0.0	0.0	3.0

			RBVs												
LMY Sire Group	**Block**	**SIRE**	**bwt**	**wwt**	**pwt**	**hcwt**	**pcf**	**ccfat**	**cemd**	**pemd**	**pfec**	**dressperc**	**lmy**	**imf**	**shearf5**
Low	1	WARATAH-090577	0.48	10.7	17.1	-0.31	-0.22	0.33	-0.35	0.90	18.03	0.14	-1.24	0.79	-2.90
Low	2	PENDARRA-075630	0.04	8.31	14.05	0.82	-0.04	0.36	0.45	2.04	38.71	0.51	-1.65	1.22	-3.61
Low	3	PENDARRA-096981	0.25	7.04	12.20	0.47	-0.39	0.33	-0.16	0.22	-9.97	0.18	-1.04	0.80	-2.90
Mod	1	WARATAH-110138	0.64	10.96	17.83	0.03	-0.13	0.31	0.23	1.62	-24.34	-0.08	-0.11	0.27	-1.78
Mod	2	WOOLUMBOOL-105317	0.56	9.17	14.41	0.67	-0.14	-0.20	0.42	2.11	-63.20	0.05	0.87	-0.28	2.63
Mod	3	LINTON-070644	0.51	10.84	15.76	0.24	-0.21	0.38	-0.41	0.71	5.39	-0.38	0.09	0.10	2.15
High	1	WUNNAMURRA-110173	0.65	13.13	19.24	0.46	-0.34	-0.38	0.04	2.21	-27.03	-0.10	1.34	-0.46	4.99
High	2	MAJARDAH-090617	0.32	8.92	13.43	0.91	-0.07	-0.19	1.50	4.01	-62.45	0.63	1.65	-0.80	2.77
High	3	VALMA-060349	0.46	9.94	15.41	1.31	-0.71	-1.14	0.20	0.72	-38.59	-0.44	1.53	-0.75	6.51

EWES n=648	**SIRE Overlay Lean Meat Yield** RBV level	**SIRES 9** n = 72/sire	**GESTATION NUTRITIONAL TREATMENT (fully randomised)** **CS 2.5** n=9/sire/trt/rep	**CS 3.0** n=9/sire/trt/rep	**CS 3.5** n=9/sire/trt/rep
36	Low	1	BLOCK1	BLOCK1	BLOCK1
36	Mod	2	REPLICATE 1	REPLICATE 1	REPLICATE 1
36	High	3	36 ewes	36 ewes	36 ewes
36	Low	1	BLOCK1	BLOCK1	BLOCK1
36	Mod	2	REPLICATE 2	REPLICATE 2	REPLICATE 2
36	High	3	36 ewes	36 ewes	36 ewes
36	Low	1	BLOCK2	BLOCK2	BLOCK2
36	Mod	2	REPLICATE 1	REPLICATE 1	REPLICATE 1
36	High	3	36 ewes	36 ewes	36 ewes
36	Low	1	BLOCK2	BLOCK2	BLOCK2
36	Mod	2	REPLICATE 2	REPLICATE 2	REPLICATE 2
36	High	3	36 ewes	36 ewes	36 ewes
36	Low	1	BLOCK3	BLOCK3	BLOCK3
36	Mod	2	REPLICATE 1	REPLICATE 1	REPLICATE 1
36	High	3	36 ewes	36 ewes	36 ewes
36	Low	1	BLOCK3	BLOCK3	BLOCK3
36	Mod	2	REPLICATE 2	REPLICATE 2	REPLICATE 2
36	High	3	36 ewes	36 ewes	36 ewes
	Total sires = 9	sires/block	3	3	3
		blocks	3	3	3
		reps within block/CS	2	2	2
		ewes/sire/rep	12	12	12
		Total ewes/CS	216	216	216
	BREEDING OVERLAY		**EWE MANAGEMENT OVERLAY - GESTATION**		

NOTES:
Ewes required for AI = 960
Ewes managed as three 320 ewe blocks unitl scanning

NOTES:
Allocation to gestation condition score treatment at scanning
Stratified randomisation based on parity and CS

Figure 1. Design of breeding and gestational nutrition component of the Nutrition & LMY experiment. The design is based on successful AI of 648 ewes to 9 sires of varying genetic potential for lean meat yield (72 ewes per sire). Three sires will be used in each of 3 blocks (216 ewes per block) with each block consisting of 2 replicates of 3 gestational CS treatments. This will produce 18 management groups of ewes (36 ewes per management group) each with a range of genetic potential for lean meat yield.

PRE WEANING NUTRITION **All ad libitum** Maintain in replicates	**LAMB FEEDLOT SYSTEM** **Maximum growth rate to 7 months of age (approx 45kg)** High E High P	High E Mod P	Mod E High P
BLOCK 1 Approximately 162 male lambs target 22kg weaning turnoff to feedlot	BLOCK1 54 male lambs 13 MJ/kg ME 24% CP	BLOCK1 54 male lambs 19% CP 13MJ/kg ME	BLOCK1 54 male lambs 24% CP 11MJ/kg ME
BLOCK 2 Approximately 162 male lambs target 22kg weaning turnoff to feedlot	BLOCK2 54 male lambs 13 MJ/kg ME 24% CP	BLOCK2 54 male lambs 19% CP 13MJ/kg ME	BLOCK2 54 male lambs 24% CP 11MJ/kg ME
BLOCK 3 Approximately 162 male lambs target 22kg weaning turnoff to feedlot	BLOCK3 54 male lambs 13 MJ/kg ME 24% CP	BLOCK3 54 male lambs 19% CP 13MJ/kg ME	BLOCK3 54 male lambs 24% CP 11MJ/kg ME

sires/block	3	3	3
blocks	3	3	3
total CS cells within block	6	6	6
ewes/sire/rep/feedlot system	4	4	4
Male lambs	162	162	162

MANAGENT - LAMBED	**MANAGEMENT OVERLAY - FEEDLOTTING**
NOTES: Maintain in reps from gestation	**NOTES:** Allocation to treatment to balance for sire x CSrep within block

Figure 2. Design of post-lambing ewe and lamb management to weaning and allocation of approximately 486 male progeny to feedlot treatments designed to deliver 1) high protein and high energy, 2) moderate protein and high energy, and 3) high protein and moderate energy to a finishing age of 7 months of age or average live weight of 45kg.

Grazing management and pasture measurements

The 18 management groups were allocated to groups of paddocks (systems) from the EverGraze site for rotational grazing. The pasture systems that are present on the EverGraze site and their performance have been previously described by Ward *et al.* (2013) and Clark *et al.* (2013). Different pastures systems were aligned with the separate blocks so that influence of pasture system is in the blocking effect. Maintenance phosphorous fertiliser was applied to all pastures prior to the autumn break.

Grazing management aimed to achieve the targeted ewe condition scores at lambing and careful planning of the rotations were used to avoid any detrimental effects (e.g. grazing on wet/waterlogged paddocks and overgrazing) on animals as well as pastures. Pre-grazing of paddocks and/or supplementary feeding (barley and hay) was also used for the treatments to achieve either higher or lower condition score. In addition, the timing of grazing rotations were based on slower rotations restricting FOO for longer to achieve lower CS and faster rotations to achieve higher CS.

Measurements of feed available/feed on offer (FOO), botanical composition were made as necessary, primarily to inform grazing management. Feed on offer measures were conducted pre and post grazing using a rising plater meter that was calibrated by cutting 16 quadrats ranging from high to low in herbage dry matter for each of the sown species across the site. Botanical composition was assessed visually and using botanical composition estimated with the dry-weight rank method (BOTANAL; t'Mannetje and Haydock 1963; Tothill *et al.* 1978). Toe cuts of samples were sorted into green and dead sown species, green and dead weeds and green and dead clover. Sorted samples were dried at 60°C for 48 hours and percent dry matter calculated. Botanical composition and feed quality measurements by NIR were conducted approximately bi-monthly during the experimental period whilst the animals were grazing on the former EverGraze site.

Ewe lambing management and measurements

Nutritional restriction or supplementation to meet CS/gestational treatments ceased at lambing upon allocation to lambing paddocks and following liveweight and condition score measures. At lambing, paddocks were allowed to grow to unrestricted levels of FOO thereby allowing ewes to increase intake, if required. This was achieved by set-stocking ewes for 5-6 weeks within each system through to lamb marking. Ewes were lambed across 2 plots/paddocks in each of the systems, plus the Tall Wheatgrass (TWG) Hedgerows. This allowed increased access to the shelter for a portion of the ewes reducing weather risks to lamb survival. The more vulnerable ewes in each system (twins, and a few of those with lowest CS and any ewes with triplets) were placed in the TWG plots. The nutrition of all ewes in terms of FOO was kept as similar as possible from lambing onwards.

Measurements on ewes and lambs at lambing were largely based on those used by the Sheep CRC as described by Brien *et al.* (2010), together with some additional measurements regarding dystocia (autopsy). From the commencement of lambing, twice-daily lambing rounds were conducted. All newborn lambs received an ear tag with a unique number and were identified with their dams within 18h of birth. Lamb status (alive or dead), sex (male or female), type of birth (single, twin, triplet or higher order birth) and lamb birth weight were recorded. Autopsy was conducted to determine cause of death for all dead lambs as per the detailed methodology of Holst (2004).

Any observed natural mismothering/adoption/stealing of lambs was not corrected. However, if ewes, failed to return to the lamb due to the conduct of measurement rounds, short term isolation (48hours) of the ewe and lamb in a lambing ring was used to encourage ewe/lamb bonding.

Lamb production management and measurement to weaning

Following lambing, all ewes within each CS replicate were retained within their gestation management groups until weaning on the 18 systems on the EverGraze site. All ewes were rotationally grazed to allow free access to the prevailing level of feed on offer with primary aim of maximising lamb growth rates. Lambs and ewes were weighed at marking and approximately every 3 weeks to enable determination of liveweight of ewes and growth rate of lambs. All systems were allowed to recover with management groups treated under similar management and nutritional conditions. Lambs were imprinted with supplements to be fed prior to weaning. Ewes that were lost to the study, at lambing for health or other reasons, were not replaced.

Parasite management of ewes and lambs

All management groups in the experiment were subjected to a bulk worm egg count (WEC) monitoring on a 4 to 6 week basis depending on seasonal conditions and level of WEC. A bulk WEC on lambs was performed at marking and weaning. Ewes and lambs were then drenched subject to veterinary advice based on the assessed level of WEC. An individual WEC sample was collected from all ewes at lamb marking as they had reach the threshold for drenching based on bulk WEC conducted at prior to lamb marking. Other preventative animal health practices were implemented such as 6:1 Vaccination at both marking and weaning. Preventive flystrike treatments (e.g. Clik) will be applied at marking to both ewes and lambs.

Lamb backgrounding management and measurement to finishing

Lambs were weaned at 12 weeks of age in December. Beyond weaning, wether lambs were maintained within their existing management group whilst weaned ewes and weaned ewe lambs were returned to the Hamilton farm. The adult ewes were shorn and the fleece weight recorded and sample of wool was taken for measurement of yield, fibre diameter, staple length and staple strength.

Male lambs were run in 3 mobs comprising all male progeny produced from within the 3 block/AI groups. Lambs were grazed on pastures available at the time and fed increasing amounts of barley, as the quality of pastures declined due to the end of the growing season.

Live Animal Dual X-Ray Absorptiometry (DXA)

Each male lamb was DXA scanned on a Hologic Discovery A Fan Beam Dual Energy X-Ray Densitometer (DXA: Hologic Inc., Waltham, MA, USA) equipped with body composition software at 2-3 weeks post-weaning prior to entering the induction period for the feedlot and 4 weeks prior to slaughter (Pearce *et al.* 2009). Using the low and high energy beams as they pass through the body, the body composition software calculates the ratio of soft tissue attenuation (RST). The attenuations of bone-free lean tissue (RL) and pure fat (RF) are known from theoretical calculation and in vitro measurements. Thus, equations for each X-ray energy level with two unknown factors can be solved to calculate the proportion of lean tissue and fat in each pixel containing soft tissue only (Hologic Inc.).

To minimise errors associated with water and feed in the gut-lumen at DXA scanning, lambs were curfewed off feed and water for 18 hours prior to scanning. Lambs were sedated with stresnil (azaperone – 1 ml per 20 kg liveweight) and ketamine (1 ml per 12 kg liveweight) into the jugular vein and transferred to the DXA instrument table and placed lying on their brisket / chest / stomach with their hind legs extended caudally and their head placed in a foam tray and held in place with a rubber elastic to minimise movement during scanning. After DXA scanning, lambs were transferred to recovery pens and their respiration and recovery monitored. Once lambs had recovered they were given access to Lucerne hay and water prior to be returned to their paddock feedlot pen.

All 3 blocks of lambs were scanned post-weaning but due to complications and poor recovery from anaesthesia only block one and part of the second block of lambs were able to be assessed at the mid-feedlot finishing phase scanning that occurred prior to slaughter. The Hologic Instrument and Software DXA measurements of lean, fat and ash percentage of the live animal were also adjusted according to equations developed from the full dissection of lambs.

Lamb finishing management and measurement

Prior to the DXA scanning and entering the finishing system, lambs were shorn, drenched, vaccinated and introduced to the ration on which they were fed during the finishing phase. The introduction of the pelleted ration was conducted based on recommendations for grain feeding contained within the DPI drought feeding notes with the amount of pellet ration being fed steadily increased over an 18 day period whilst the lambs were given ad libitum access to Lucerne hay.

The allocation of lambs into finishing system pen and diet was based on the dam. For this placement, the dam is the birth dam as distinct from the rearing dam, because only the birth dam carries the sire genetics treatments. For each of the three experimental blocks, there was one pen of each of the three finishing systems, giving a total of 9 pens, each of which contained the surviving male progeny of 72 ewes (Figure 2).

Feedlot ration treatments were based on three commercially manufactured pellets (Five Star Stockfeeds) with differing levels of metabolisable energy (ME) and crude protein (CP). The ingredients used in the ration and the composition of the pellet were allowed to vary in order to meet the different levels of ME and CP required in the pellet rations.

The three diet/ration treatments were:

- High Energy, High Protein – tested at 13.2 MJ ME/kg DM and 24.2% CP;
- High Energy, Moderate protein – tested at 13.0 MJ ME/kg DM and 19.2% CP;
- Moderate Energy, High protein – tested at 11.0 MJ ME/kg DM and 23.7% CP.

All lambs were fed using self-feeders in each pen with ad libitum access to barley straw in hay cradles. The amount of pellets fed and consumed in each pen was recorded and samples of each ration were taken upon the filling of feeders during the finishing period. The pellets, barley straw and Lucerne hay were tested for nutritive value by NIR.

Lamb slaughter

Lambs were slaughtered sequentially in April and May 2013 on three slaughter dates consistent with the three AI groups/blocks such that all treatments were represented at each slaughter. A half-carcass from each lamb was cut into primals and DXA scanned prior to either full or partial dissection to determine lean meat yield. Samples were collected for analysis of shear force, intramuscular fat (IMF) and retail colour. All slaughter were yarded the day before slaughter, weighed after a 6 h feed and water curfew, transported to abattoir lairage and slaughtered the following day in a commercial abattoir. Lambs were slaughtered at the same abattoir to reduce variation in meat quality parameters observed between abattoirs (Pearce *et al.*, 2010).

Meat quality sampling and measurement

Carcasses were not electrically stimulated post-dressing as this was not available at the abattoir used for slaughter. The carcases were trimmed according to AUS-MEAT specifications (Anon. 1998) and carcase weight measured. A 10g sample of subcutaneous fat from the hind quarters (above the tail) and a 10g sample of muscle tissue (taken from the m. longissimus lumborum (LL)) were taken at approximately 1hr post-slaughter. Samples were placed in individually labelled tubes and frozen on liquid nitrogen prior to long-term storage at -80°C. Carcasses were measured and sampled for carcass and meat quality traits after they had been chilled overnight at 0-2°C. All samples from the same slaughter day and block were kept together for sampling and measurement.

The pH and temperature of the LL of each carcass was measured 4 times post-slaughter as described by Pearce *et al.* (2010). The rate of decline in pH and temperature during the first 24 h post-mortem is defined by; (1) the pH of the LL when the LL reached 18°C (pH18), and (2) the temperature of the carcass when the carcass reaches pH6 (pH6TEMP). These values were calculated as described by Pearce *et al.* (2010).

Fresh meat colour was measured 19–24 h after slaughter (one day post-slaughter) using a Minolta chromameter, D65 illuminant with a 2° standard observer and 8 mm aperture. The chromameter was calibrated on a white tile before measurements and the values recorded were L* (lightness), a* (redness) and b* (yellowness). Prior to measurement, each carcass was cut at the 12th rib through the LL and the cut surface was exposed to air for 30–40 min at 2-4°C. Measurements were taken in triplicate and the mean used for analysis.

The eye of shortloin (LL) was removed from the right side of the carcass and the subcutaneous fat and epimysium (silver skin) removed. The topside, cap off *(m. Semimembranosus*, SM), was removed from the right side hind-leg. A 65 g sample of the SM was vacuum packed and frozen at -20°C on day 5 post-slaughter and subsequently analysed for compression. Two 40 g diced samples of the LL were collected and frozen one day post-mortem at -20°C and for mineral and intramuscular fat analysis and subsequently freeze-dried. A 4 g sample of the SM was be placed in a 5 mL tube, frozen at -20°C on day 1 post-slaughter and subsequently analysed for total collagen content and intramuscular fat, after freeze drying. Freeze drying was conducted using a commercial freeze-drier (Cuddon FD 1015; Cuddon Freeze Dry, Blenheim, NZ). A 5 cm portion of loin was be taken from the cranial end of one of the short loin, packed in a vacuum-sealed gas-impermeable plastic bag and stored at 4°C for subsequent retail colour measurement. Two 65 g samples were taken from the LL for shear force measurement, one from the middle of the LL and one towards the cranial end. The cranial and middle samples were used to measure shear force on days 1 and 5 post slaughter. Each sample will be vacuum packed and frozen at -20°C, immediately in the case of the day 1 sample (SF1) and after storage at 2-4°C for 4 days for the day 5 sample (SF5).

The sample preparation and cooking method for shear force was based on the method published by Hopkins and Thompson (2001) for lamb. A water bath was pre-heated to 71°C and samples were taken directly from the freezer and placed in the water-bath and cooked for 35 min. The allocation of samples to cooking batches will be recorded. Subsequent to cooking, all samples will be cooled in running water for 30 min. The day after cooking, six sub-samples ~3–4 cm long and 1 cm2 in cross-sectional area will be cut from each sample, ensuring that the muscle fibres ran along the long axis of the sample and avoiding any fat or connective tissue. A texture analyser (Lloyd Instruments, Hampshire, UK; Model LF-Plus) set at a cross head speed of 300 mm/min and fitted with a 1 kN load cell and an inverted V-blade positioned perpendicular to muscle fibre orientation will be used to shear and measure the samples.

Retail colour measurement was commenced at 5 days post-slaughter. To simulate retail display, each sample will be re-sliced to a thickness of 3 cm to provide a fresh surface, placed on a black styrofoam tray (12 × 12 cm), bloomed for 30–40 min and then overwrapped with oxygen permeable polyvinyl chloride film of 15 μm thickness. Samples will be held in a chiller for 2 days at 3-4°C under constant lighting at the surface of the meat (~1000 Lux using a 58 W Nelson fluorescent tube for meat display). Colour will be measured on day 1, day 2 and day 3 of display using a Hunter Laboratory Mini Scan instrument (Model 45/0-L; aperture size = 25 mm, illuminant D65, standard observer 10°, calibrated with black and white tiles). Measurements will be taken without removing the overwrap, replicated once after rotating the spectrophotometer 90° in the horizontal plane and the mean of these 2 readings will be used for analysis. The oxy/met ratio will be calculated by dividing the percentage of light reflectance at a wavelength of 630 nm by the percentage of light reflectance at a wavelength of 580 nm (Hunt *et al.* 1991) for days 1, 2 and 3 of display. The oxy/met ratio on day 3 of display was defined as the retail colour stability.

Carcass Dual X-ray Absorptiometry

The right side of the carcass of each lamb was broken into the primal cuts boxed and transported at 4°C to Hamilton for DXA analysis using a Hologic Discovery A Fan Beam Dual Energy X-Ray Densitometer (DXA: Hologic Inc., Waltham, MA, USA; Dunshea *et al.* 2007). The leg was removed at the first chine bone alongside the end of the hip bone. The shoulder split off between the 5/6th rib in a straight line (not along the rib) and the belly section was cut from the middle in a straight line across the rib section leaving a tail on the loin of approximately 5cm. Each of the primal cuts were placed on the DXA table and scanned using the instrument and a whole carcass lean, fat and ash estimate derived using Hologic software(Dunshea *et al.* 2007) that was later adjusted using the equations derived from full dissection of the carcass.

This information along with DXA, muscle and fat weight measurements obtained on all carcases was used to predict lean meat yield for each non-dissected lamb using a derived regression equation. Existing predictions for sheep regional carcase composition demonstrate predictions (R^2) of between 0.94 -0.98 for lean and between 0.80 – 0.88 for fat (White *et al.*, 2012) developed from 64 mixed age Merino and x-bred lambs selected for variation in carcase weight and fatness from 2371 individuals.

Lean meat yield measurement by carcass dissection

The lean meat yield was also measured directly through full and partial carcase dissection of each half carcass to derive the weight of muscle, fat and bone from a carcase. Twelve half-carcasses were randomly selected from each feedlot pen per slaughter date for full dissection into muscle, fat and bone component within each region. The random selection was weighted by proportion of single and twin bearing ewes at the slaughter.

A partial dissection was performed on the all the remain half carcasses from each kill using method of Pearce et al (2010) and lean meat yield predicted according to the equation of Gardiner et al (2010).

Statistical analysis

Separate analysis for multi-parous and single bearing and all ewes, and the progeny of those ewes was conducted across all traits and measurements undertaken. The analysis included the analysis of all ewes and progeny at any particular sampling point or measurement time. Multi-parous ewes included twin ewes and a triplet ewe. Analyses were also conducted on the basis of the scanned parity and/or the observed parity at birth. The unit of analysis was the average of all ewes or lamb/s of appropriate ewe parity, in the same mob, pen, ration and/or sire combination depending on the analysis being undertaken.

An initial analysis of variance for each trait was undertaken using the full design structure incorporating CS, feedlot diet and sire group. The data used were averages over all available animals (singles and multiples) known to be in same system (pregnancy group), same feedlot pen and same sire. This was used to determine the presence or absence of a main effect due to treatments and interactions between treatments. A subsequent analysis of variance was then conducted to assess effects of the main treatment either CS, feedlot diet and LMY sire group separately. All analyses were undertaken using Genstat (GenStat Committee 2011).

For some measurements, with a few discrete values, the P-value has been calculated using a Permutation Test appropriate for the design, rather than using the F-Distribution. This allowed the use of a non-parametric test while still using the appropriate analysis of variance. P values, that are calculated using a permutation test, are marked in the results.

Analysis after adjustment for liveweight

To examine the effect of CS treatment on some traits and measures after allowing for the effect of differences in lamb weight, a general linear model was fitted to ewe management group values with terms for block, CS treatment and a linear response to hot carcass weight. Thus, a model was fitted with parallel linear responses of hot carcass weight for each combination of block and CS treatment, but with the added restriction that the intercepts were obtained additively from block and CS treatment. Adjusted treatment means were adjusted for blocks, as well as the lamb weight response.

Lamb liveweight change

For the analysis of live weight change, an analysis of average relative live weight change, over a period of time was also conducted. This is an important measurement as differences in this measurement determine the extent that growth over a period deviates from being purely proportional to the size of the animals at the start of a period. The average relative live weight change (% increase per day), over a period of time was calculated as;

$$\frac{(\ln(\text{live weight at end of period}) - \ln(\text{live weight at start of period}))}{\text{length of period}}.$$

Lean meat yield

Lean meat yield in the project was assessed by DXA, full carcass dissection and partial carcass dissection. As consequence, it was possible to analyse a number lean meat related variables arising from this methodology.

The following points define the measurements that were assessed in the analyses presented in this report.

- Three muscle yield: Sum of weights of loin, topside and round muscle divided by the hot carcass weight, then multiplied by 2 and converted to a percentage.
- Loin yield: Weight of loin muscle divided by the hot carcass weight, then multiplied by 2 and converted to a percentage.
- Topside yield: Weight of topside muscle divided by the hot carcass weight, then multiplied by 2 and converted to a percentage.
- Round yield: Weight of round muscle divided by the hot carcass weight, then multiplied by 2 and converted to a percentage.
- Leg yield: Weight of leg muscle divided by the hot carcass weight, then multiplied by 2 and converted to a percentage.
- Two bone yield: Sum of weights of leg and H bones divided by the hot carcass weight, then multiplied by 2 and converted to a percentage.
- LMY predicted from kill and DXA adjusted lean: Calculated best parallel, with respect to block (kill), linear response to DXA lean (%) from full bone out data. Then calculated a predicted LMY for each animal.
- LMYpred = LMY for lambs having full bone out
    - LMYpred = 22.180 + 0.5337 × DXA lean (%), for lambs in first kill without full bone out
    - LMYpred = 24.614 + 0.5337 × DXA lean (%), for lambs in second kill without full bone out
    - LMYpred = 21.616 + 0.5337 × DXA lean (%), for lambs in third kill without full bone out
- LMY predicted from kill and DXA adjusted lean with random error: Same as LMY predicted from kill and DXA adjusted lean, except that a normal random error has been added to each prediction for lambs without full bone out. This error term had a mean of 0 and residual standard deviation equal to 1.69, which was the residual standard deviation for the parallel, with respect to block (kill), linear response to DXA lean (%) from full bone out data. This process provides almost identical means to LMY predicted from kill and DXA adjusted lean, but the SED and P values are more realistic.

Retail colour and colour stability

For each of the 4 days of retail display, an average over all available animals (singles and multiples) known to be in same system (pregnancy group), same feedlot pen and same sire was calculated. Then, for each of the 4 display days, a single value is obtained for each of the replicates representing the key treatments of either CS, feedlot diet or LMY sire group. In some cases, the average will be calculated over less than the total number of combinations available as there was no measurement on any animal from a particular combination of system, feedlot pen and sire. An analysis of variance was then conducted using a Greenhouse Geisser correction for repeated measures.

For some colour measurements, the effect of CS treatment, after adjusting for hot carcass weight, is estimated. This estimation is calculated from an analysis on average values, over the 4 display days, using a general linear model with additive terms for block, a linear response to hot carcass weight and CS treatment, and using a grazing system as the observational unit. For measurements restricted to a subset of the population (*e.g.* scanned multiples, birth multiples), the hot carcass weight calculated for each grazing system was restricted to lambs belonging to that subset of the population.

Analysis against LMY sire group
In the first instance, an average over all available lambs (singles or multiples or singles and multiples combined) known to be in the same system (pregnancy group), same feedlot pen and same sire was calculated. Then a single value was obtained for each of the 9 sires by averaging over the relevant (up to 18) calculated values in the previous stage. In many cases, the average was calculated over less than 18 values because there was no measurement on any lamb from a particular combination of system, feedlot pen and sire. A randomised block analysis of variance with LMY Sire grouping as treatment, kill groups as blocks and sire as the unit of analysis was then conducted. The effect of LMY Sire grouping was then divided into 2 orthogonal contrasts, namely (1) high group versus average of low and moderate groups and (2) low versus moderate group.

4. Results

The following results section has been structured to follow the results obtained at each stage of the experimental process starting with the details of the nutritional management during gestation of the ewes and lambs and then describing the nutritional value of forage and feeds fed during backgrounding and the finishing phase.

The impacts of gestational nutrition on the ewe are then shown to establish that each of the CS treatments were successfully able to result in divergence of CS by lambing. The impact of these CS treatments on lamb survival, birth weight and growth to weaning are then detailed. The overall performance of lambs in the feedlot is described briefly prior to the full presentation of results for lamb finishing, slaughter performance, carcass traits and meat quality.

The statistical analyses detected very few significant interactions between gestational CS, finishing diet and/or lean meat yield sire group. For many of the interactions detected in the study, the main effect of the treatment was also often not significant and/or the interaction was weak or isolated and not consistent with other results. These interactions may well be chance effects. In the absence of conclusive evidence on major interactions this report therefore focuses on the results of the main effect analyses for the three main treatment regimes, such that the separate effects of the CS treatment during pregnancy on the ewe, finishing ration/diet and LMY sire group are reported.

Nutritional management

Feed on offer and nutritive value during pregnancy and lactation
Feed on offer (FOO) indicates the total amount of dry matter (kg dry matter per ha) that was available to the ewes for consumption. Pre-grazing measurements of FOO were taken prior

to each paddock rotation. During the mid-pregnancy to lambing period, there were differences in the level of feed on offer between each of the CS treatment groups (Figure 3). The CS3.5 treatment group generally had the highest feed on offer levels and CS2.5 the lowest.

Supplementary feeding of barley to the CS 3.5 treatment ewes occurred from the 16th July until the start of lambing at the beginning of September. Only ewes from the CS 3.5 treatments received barley supplementation, with rate of supplementation slowly increasing from 50g/head/day up to 300g/head/day immediately prior to lambing. In total, ewes in the CS3.5 treatment were fed 9.9kg of barley per ewe during this period. Feeding of supplementary pasture hay only occurred for the CS 2.5 treatment ewes during the last 16 days of pregnancy prior to lambing at a rate of ~324g/head/day. These ewes received an approximate total of 5.2kg/head during this period.

At lambing all of the treatment groups were given access to similar feed on offer levels (1.8 – 2.2 t DM/ha; Figure 4) and there continued to be no differences in feed on offer between the treatment groups through to weaning.

Nutritive characteristics of pastures grazed over the duration of the experiment are shown in Table 2. There were generally no differences in CP, NDF, *IV*DMD or estimated ME between the CS treatment groups, therefore the averages for each pasture species are presented. At lambing in September, the ewes were predominantly grazing the perennial ryegrass pastures which had an average CP content of 16.1% with 12.0 MJ ME/kg DM. Over the period of lactation, the perennial ryegrass swards continued to have ME levels above 12 MJ/kg DM and experienced an increase in CP to 23.0%DM in October 2012.

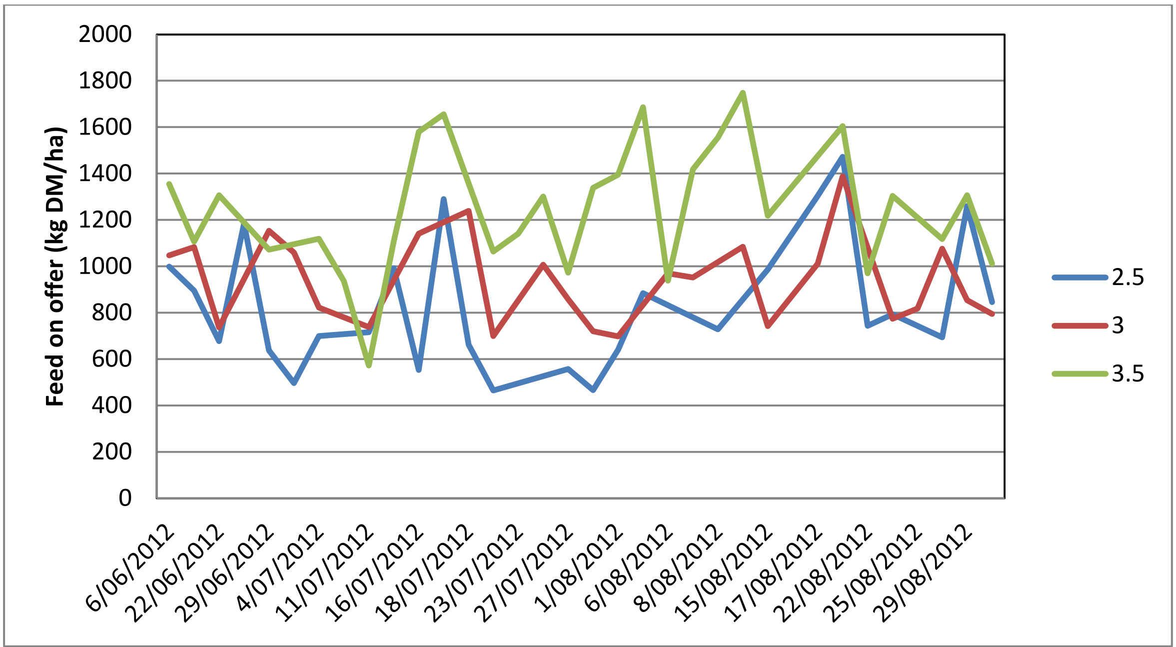


Figure 3. Feed on offer levels (kg DM/ha) during the mid-gestation to lambing period for the CS2.5, CS3 and CS3.5 treatments.

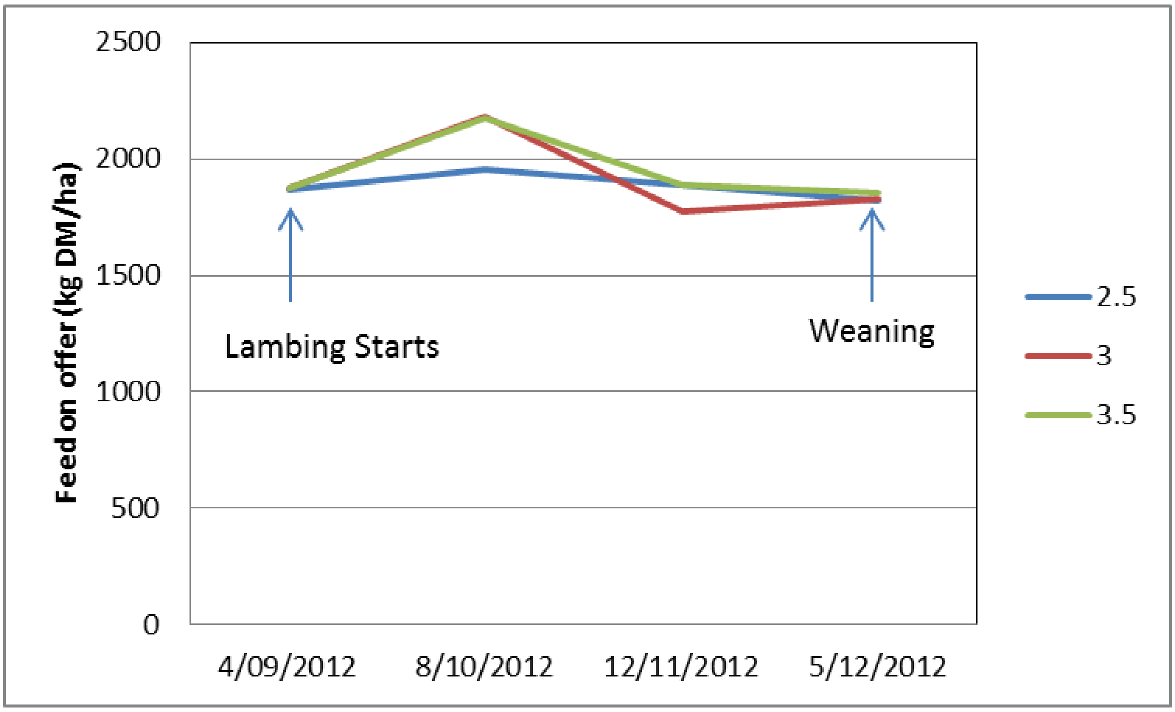


Figure 4. Feed on offer levels (kg DM/ha) during the lambing to weaning period for the CS2.5, CS3 and CS3.5 treatments.

Table 2. Nutritive characteristics of the Lucerne, perennial ryegrass and tall fescue pasture during the experimental period, averaged across CS treatments.

		CP (%DM)	NDF (%DM)	*IV*DMD (%DM)	ME (MJ/kgDM)
Jun 2012	Lucerne	26.08	35.52	74.43	11.20
	Ryegrass	23.98	44.57	76.87	11.60
	Tall Fescue	18.33	54.77	69.20	10.30
Jul 2012	Lucerne	26.13	40.23	71.47	10.68
	Ryegrass	23.62	45.89	76.51	11.55
	Tall Fescue	24.83	49.60	74.87	11.27
Sep 2012	Lucerne	22.23	45.50	78.15	11.83
	Ryegrass	16.12	44.33	79.21	12.01
	Tall Fescue	16.11	51.36	68.15	11.72
Oct 2012	Lucerne	22.75	42.10	78.75	11.90
	Ryegrass	23.00	43.47	81.67	12.43
	Tall Fescue	16.30	52.20	73.70	11.10

Lamb backgrounding at pasture

Prior to entering the feedlot, the male lambs grazed were grazed at pasture and also had supplementary feeding of barley and pasture grass hay. The nutritive characteristics for the fresh pasture, grass hay and barley fed out during this period are shown in Table 3. All three block/groups of lambs had access to similar pasture and the same rates of supplementation on a per head basis which was gradually increased as the pasture dried off.

Table 3. Crude protein (CP) (%DM), neutral detergent fibre (NDF) (%DM), digestibility of organic matter (DOMD) (%DM) and metabolisable energy (ME) (MJ/kg DM) content of fresh pasture, grass hay and barley fed to lambs in the backgrounding period prior to entry to the feedlot.

Date	Feed type	CP	ME	NDF	DMD	DOMD
01-08-2012	Barley	7.9	13.0	5.5*	84.9	83.7
01-08-2012	Barley	7.6	12.9	5.9*	84.4	83.2
22-08-2012	Grass hay	10.1	7.9	59.9	NC	53.7
22-08-2012	Grass hay	7.4	7.2	65.9	NC	50.1
12-12-2012	Fresh pasture	10.8	9.6	53.9	NA	62.1

*Acid detergent fibre; NC, Not Calculated; NA, Not Available

Feedlot rations – Induction and finishing

The nutritive characteristics of the feedlot rations and hay fed to the lambs during induction and finishing phase are summarised in Table 4 and 5. Nutritive characteristics were analysed when the feeders were re-filled (approximately weekly). The ME and CP content of the pellet rations complied with the requirements for the respective treatments.

Table 4. Crude protein (CP) (%DM), estimated metabolisable energy (ME) (MJ kg/DM), acid detergent fibre (ADF) (%DM), neutral detergent fibre (NDF) (%DM), digestibility (DMD) (%DM), digestible organic matter (DOMD) (%DM) and water soluble carbohydrates (WSC) (%DM) of Lucerne hay (LH) and barley straw (BS) fed to lambs in the feedlot.

Sample date	Feed type	CP	ME	ADF	NDF	DMD	DOMD	WSC
20-2-2013	LH	18.3	9.3	37.3	43.7	63.4	60.5	7.9
	BS	1.9	5.2	49.9	77.7	39.3	40.2	NA
27-2-2013	LH	16.3	8.4	34.2	44.8	60.1	55.2	6.8
	BS	2.0	5.0	45.1	76.5	39.3	39.2	NA
5-3-2013	LH	18.0	8.6	35.3	45.6	60.0	55.9	6.9
	BS	2.2	5.0	46.0	76.2	39.2	39.1	NA
15-3-2013	LH	19.1	9.4	29.2	42.4	64.0	61.0	6.8
	BS	2.3	5.4	39.8	74.1	40.5	41.2	NA
20-3-2013	LH	18.8	9.3	29.2	42.2	63.7	60.8	6.5
	BS	2.3	6.0	40.8	75.2	44.2	44.2	NA
28-3-2013	LH	18.3	9.0	30.0	43.9	61.9	59.3	6.9
	BS	2.4	5.4	40.6	73.8	41.0	41.5	NA
5-4-2013	LH	16.2	8.5	31.3	45.7	58.6	56.4	5.9
	BS	2.3	6.0	40.7	74.7	44.0	44.1	NA

NA, Not Analysed

Table 5. Crude protein (CP) (%DM), estimated metabolisable energy (ME) (MJ kg/DM), acid detergent fibre (ADF) (%DM), neutral detergent fibre (NDF) (%DM), digestibility (DMD) (%DM), digestible organic matter (DOMD) (%DM), fat (%DM), ash (%DM) of pellet rations (High ME+High CP[R1], Mod ME+High CP[R2], High ME+Mod CP[R3]) fed to lambs in the feedlot.

Sample date	Ration	CP	ME	ADF	NDF	DMD	DOMD	Fat	Ash
20-2-2013	R1	23.4	13.2	13.4	21.0	82.5	81.4	4.0	5.8
	R2	23.6	10.6	20.2	29.3	63.0	62.7	4.0	12.2
	R3	18.8	12.9	14.0	23.2	78.4	77.5	4.9	7.1
27-2-2013	R1	23.6	13.1	13.5	18.9	82.9	78.6	3.9	7.1
	R2	23.0	11.8	22.3	26.8	69.6	69.3	5.2	8.7
	R3	18.9	12.9	13.9	23.5	81.9	79.9	4.1	7.2
5-3-2013	R1	23.9	13.1	13.6	17.9	81.7	77.9	3.9	7.0
	R2	23.1	11.8	23.0	26.9	69.8	69.5	5.4	8.5
	R3	19.0	12.8	13.9	23.6	81.8	80.0	4.0	7.4
15-3-2013	R1	24.4	13.4	12.3	24.0	85.2	84.0	3.3	6.6
	R2	23.8	10.6	15.9	22.9	63.0	62.6	4.1	12.6
	R3	19.1	13.0	14.0	23.9	82.2	81.1	3.6	7.2
20-3-2013	R1	24.6	13.5	12.3	24.1	86.0	84.8	3.5	5.9
	R2	23.8	10.7	16.1	23.1	61.8	61.5	5.1	12.5
	R3	19.2	13.3	13.4	24.4	83.5	82.4	4.0	6.7
28-3-2013	R1	25.3	13.1	13.2	23.4	85.1	83.9	2.4	6.3
	R2	24.6	10.7	14.7	21.5	64.4	64.0	3.9	12.9
	R3	20.1	12.9	12.9	19.5	83.2	82.1	2.5	6.9
5-4-2013	R1	24.4	13.3	13.4	26.2	84.4	83.2	3.6	7.0
	R2	23.8	11.0	16.7	24.1	60.8	60.6	6.4	12.5
	R3	19.6	12.9	14.2	22.5	82.4	81.3	2.9	6.7

Condition score treatment effects on the ewe

Ewe condition score and liveweight

Ewe CS between nutritional treatments was not different until allocation at day 58 (7/06/12) following which the three CS nutritional treatments resulted in significant CS divergence ($p<0.01$) by day 72, that then continued until day 139 ($p<0.001$) immediately prior to lambing where there was an average 0.7 CS difference between the CS3.5 and CS2.5 treatments (Figure 5c). Multiple bearing ewes were typically about 0.1 of CS lower at lambing than single bearing ewes (Figure 5a and b). Following lambing, CS converged such that CS was not different between CS3.5 and CS3.0 treatments at lamb marking and at weaning but the CS was still lower for CS2.5 treatment ewes ($p<0.01$, Figure 5c). Single and multiple bearing ewes followed similar patterns of CS change, although multiple bearing ewes appeared to converge the most by weaning (figure 5b). Single bearing ewes were 0.3 to 0.4 of CS higher at weaning than multiple bearing ewes.

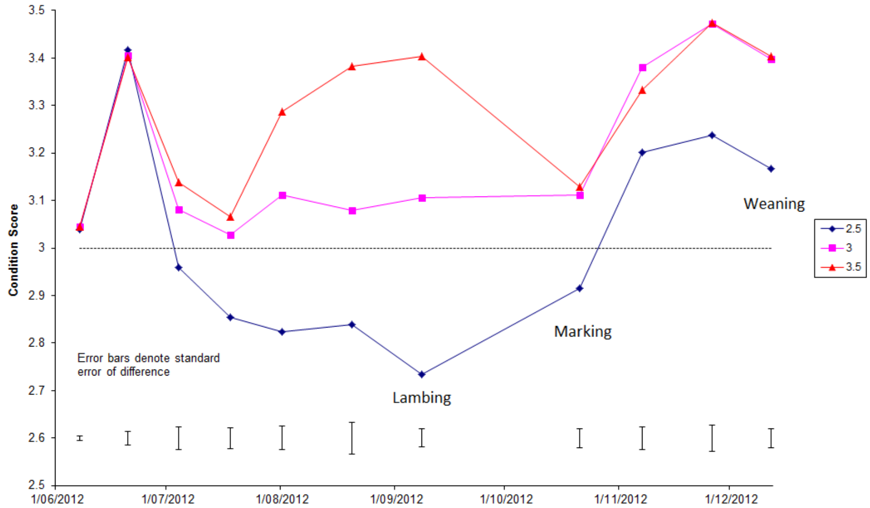
Ewe liveweight diverged significantly ($p<0.01$) following allocation on day 58 after artificial insemination, with all three CS treatments segregating by lambing to result in 13kg difference between CS 3.5 and CS 2.5 treatments at day 139 prior to lambing ($p<0.001$, Figure 6c). All CS treatments converged in liveweight due to the removal of conceptus and cessation of the CS feeding treatment at lambing. However, at lamb marking and weaning CS2.5 ewes were still between 4 and 5kg lighter than both CS3.0 and CS3.5 treatment ewes ($p<0.05$). Multiple bearing ewes were approximately between 4 and 5 kg lighter at marking and weaning than single bearing ewes (Figure 6a and b).

Ewe ultrasound eye muscle and fat depth

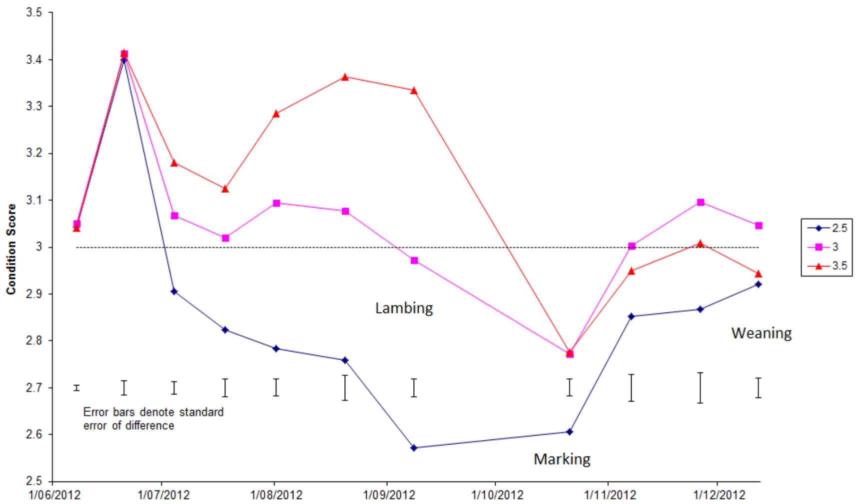
Ewe eye muscle depth was measured by ultrasound at 6 days prior to AI, at allocation (day 58), at day 119 and at weaning. Ewes averaged 26.2mm and 26.1mm at the first two measurement days with no significant differences between CS treatments as different nutritional management regimes were only implemented from day 58. At day 119 (prior to lambing), the average muscle depth was 24.7mm, 28.3mm and 30.6mm for the CS 2.5, 3.0 and 3.5 treatments respectively ($p<0.01$). At weaning ewes averaged 22.4mm, 24.2mm and 23.8mm for the CS 2.5, 3.0 and 3.5 treatments respectively ($p<0.001$, Figure 7c). Multiple bearing ewes had lower muscle depth at weaning than single bearing ewes (Figure 7a and b) but were similar prior to lambing. Multiple bearing ewes lost more muscle depth across all CS treatments than single bearing ewes to weaning resulting in a difference in eye muscle depth between single and twins at weaning of 2.3mm, 3.4mm and 5.3mm for the CS 2.5, 3.0 and 3.5 treatments respectively (Figure 7a and b)

Ewe fat depth averaged 2.7mm and 3.8mm at day -6 and 58 respectively with no significant differences. At day 119 ewes averaged 2.5mm, 4.0mm and 5.3mm for the CS 2.5, 3.0 and 3.5 treatments respectively ($p<0.001$ Figure 8c). At weaning ewes averaged 2.1mm, 2.8mm and 2.9mm for the CS 2.5, 3.0 and 3.5 treatments respectively ($p<0.001$, Figure 8c). Multiple bearing ewes had lower fat depth (0.2 to 0.4mm) prior to lambing and at weaning than single bearing ewes (Figure 8a and b). Multiple bearing ewes also lost more fat across all CS treatments than single bearing ewes to weaning resulting in a difference in fat depth between single and twins at weaning of 1.3mm, 1.7mm and 2.3mm for the CS 2.5, 3.0 and 3.5 treatments respectively (Figure 8a and b).

(a)



(b)



(c)

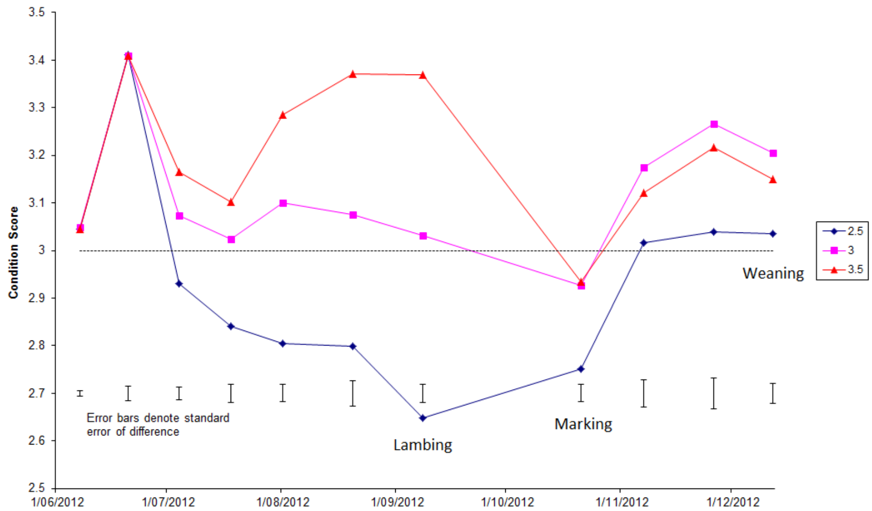
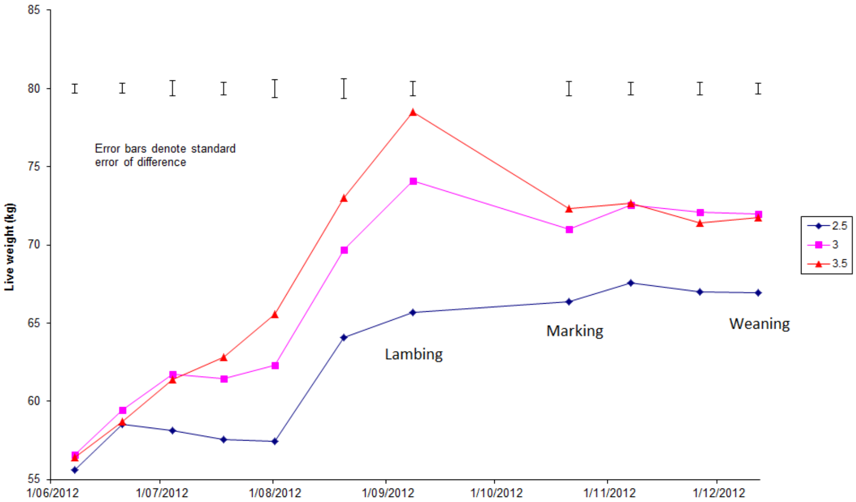
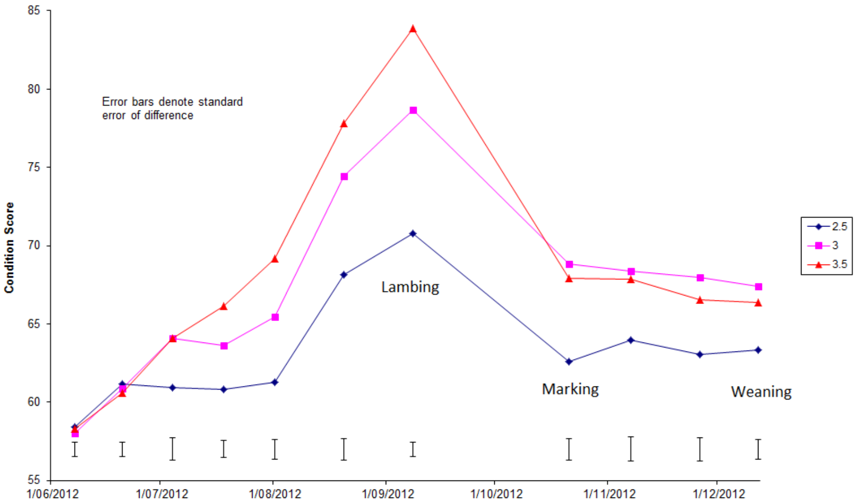


Figure 5: Effect of Condition Score (CS) treatment on observed condition score for (a) single and (b) twin ewes and (c) all ewes.

(a)



(b)



(c)

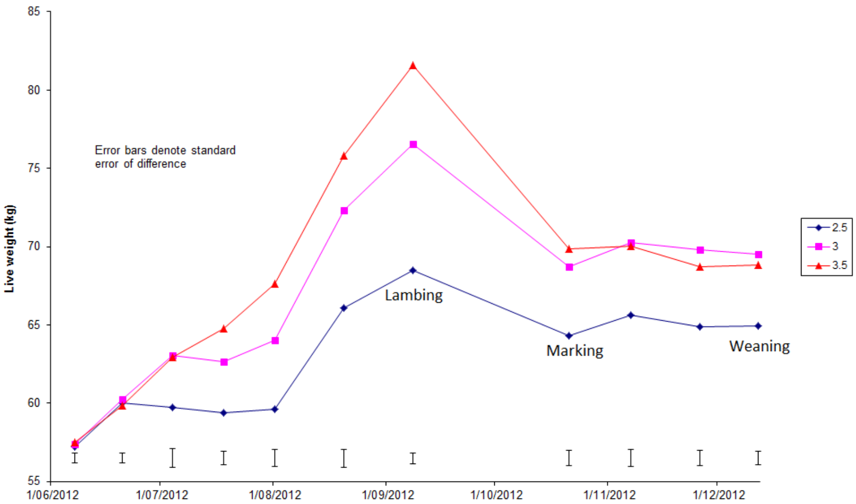
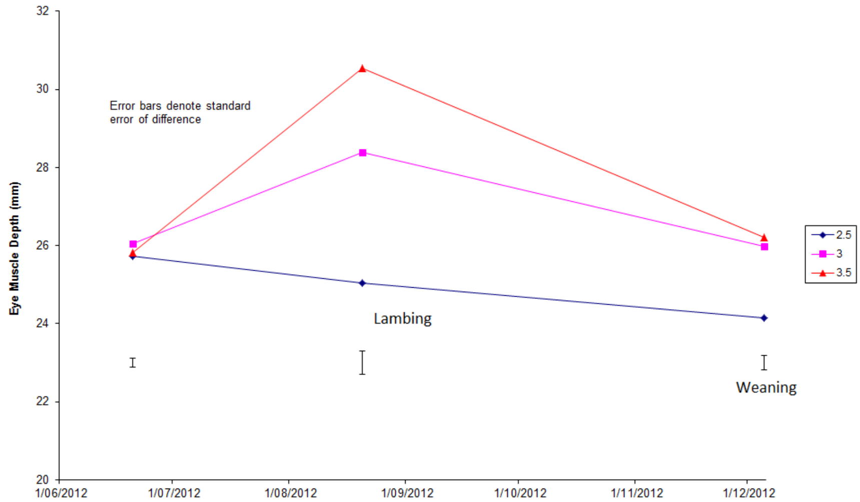
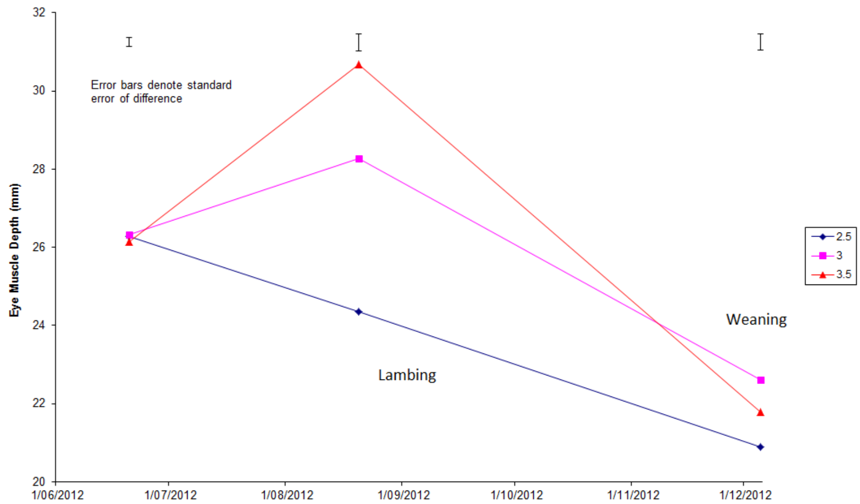


Figure 6: Effect of Condition Score (CS) treatment on observed ewe weight for (a) single and (b) twin ewes and (c) all ewes.

(a)



(b)



(c)

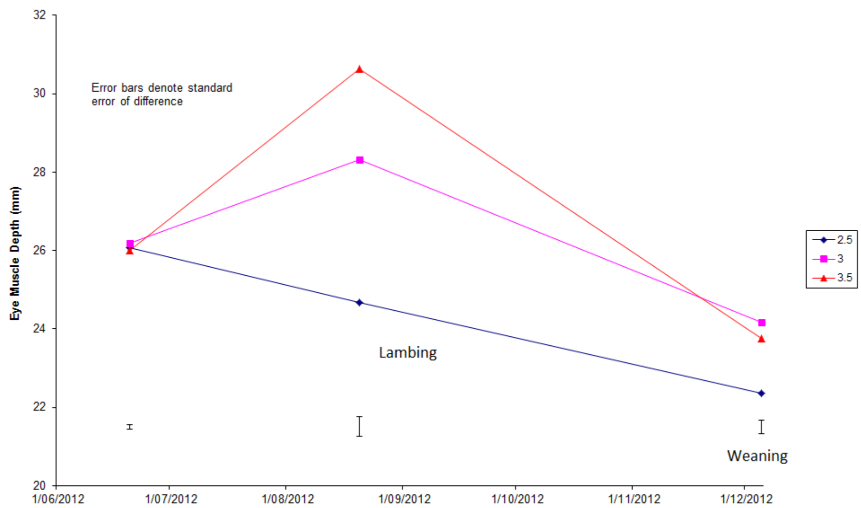
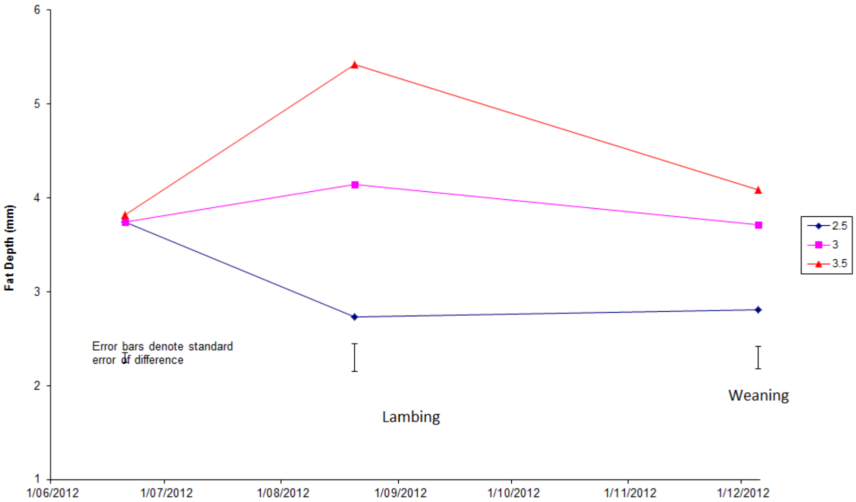
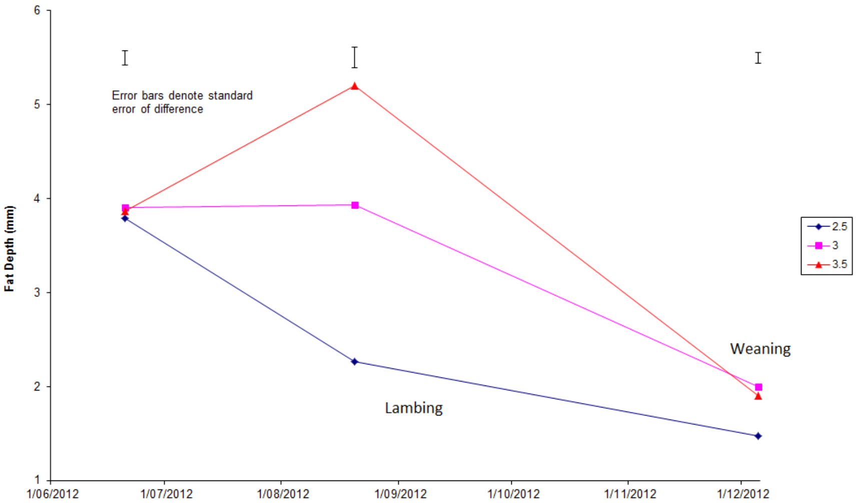


Figure 7: Effect of Condition Score (CS) treatment on eye muscle depth for (a) single and (b) twin ewes and (c) all ewes.

(a)



(b)



(c)

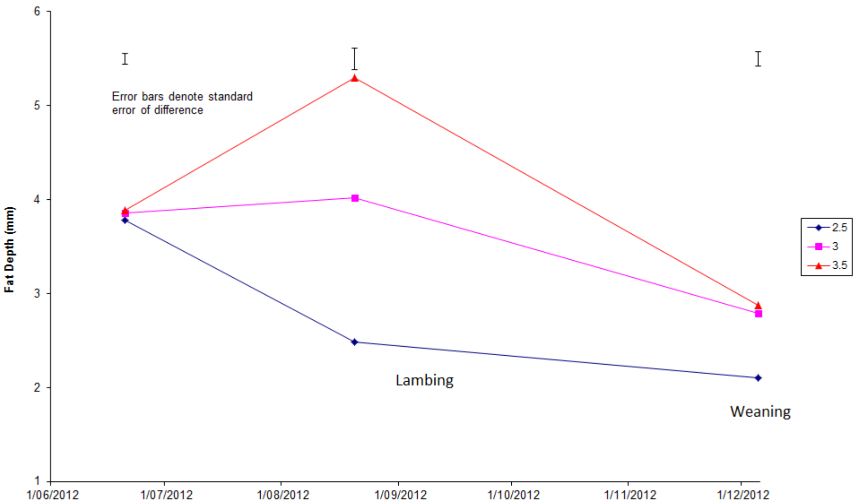


Figure 8: Effect of Condition Score (CS) treatment on fat depth for (a) single and (b) twin ewes and (c) all ewes.

Condition score and wool production in maternal ewes

Table 6 presents the wool production of adult ewes at shearing in December after weaning. The greasy and clean fleece weight was significantly reduced (~0.3-0.4kg/head) by the CS2.5 treatment compared to CS3.5. Mean fibre diameter was also reduced by ~1.4μm. The coefficient of variation of fibre diameter was greater in CS2.5 treated twin scanned ewes than the other CS treatments. Corresponding these changes staple strength was significantly affected by CS treatment with CS2.5 treatment ewes producing lower strength wool. Staple length was not significant affected by the CS treatment but there was trend towards lower length in CS2.5 treatment twins (p=0.087). Across all ewes fibre curvature was greater in the CS2.5 treatment compared to the higher CS treatments. The yield of fleece wool was unaffected by CS treatment.

Table 6. Effect of condition score (CS) treatment on wool production and wool quality of all ewes, single and twin scanned ewes shorn in December after weaning (p values in bold type are significant).

Wool Measurement	**CS 2.5**	**CS 3.0**	**CS 3.5**	**sed**	**P value**
All Ewes					
Greasy fleece weight (kg) *	3.268	3.544	3.672	0.0771	**<.001**
Yield (%)	72.01	72.25	71.70	0.534	0.595
Clean fleece weight (kg) *	2.359	2.562	2.634	0.0588	**0.001**
Mean fibre diameter (μm)	28.69	29.52	30.07	0.408	**0.016**
Coefficient of variation of fibre diameter (%)	20.62	19.46	19.31	0.375	**0.007**
Staple Length (mm)	98.05	100.54	101.47	2.021	0.253
Staple Strength (N/ktex)	43.1	53.3	57.7	2.90	**<.001**
Fibre Curvature (deg/mm)	81.83	79.08	78.35	1.214	**0.031**
Single Scanned Ewes					
Greasy fleece weight (kg) *	3.457	3.741	3.912	0.0891	**<.001**
Yield (%)	72.43	72.77	72.23	0.786	0.788
Clean fleece weight (kg) *	2.509	2.721	2.824	0.0754	**0.003**
Mean fibre diameter (μm)	28.55	29.51	29.92	0.501	**0.047**
Coefficient of variation of fibre diameter (%)	20.10	19.29	19.15	0.518	0.181
Staple Length (mm)	102.3	104.2	103.6	2.69	0.773
Staple Strength (N/ktex)	41.9	54.6	59.6	4.20	**0.003**
Fibre Curvature (deg/mm)	80.85	76.87	77.98	2.211	0.216
Twin Scanned Ewes					
Greasy fleece weight (kg) *	3.105	3.379	3.491	0.0947	**0.004**
Yield (%)	71.58	71.80	71.27	0.518	0.602
Clean fleece weight (kg) *	2.228	2.428	2.490	0.0707	**0.007**
Mean fibre diameter (μm)	28.77	29.51	30.14	0.505	0.055
Coefficient of variation of fibre diameter (%)	21.05	19.59	19.46	0.470	**0.009**
Staple Length (mm)	94.34	97.49	99.84	2.267	0.087
Staple Strength (N/ktex)	44.1	52.3	56.0	2.78	**0.003**
Fibre Curvature (deg/mm)	82.87	80.92	78.78	1.507	0.054

* Excludes belly weight. Note: The analysis is based on average of each plot/replicate mob which includes both maternal composite and 1st cross Border Leicester Merino ewes.

Lambing performance

The effect of condition score treatment on lambing numbers

Results of the condition score treatment on lambing numbers at birth and to marking and weaning are reported in Table 7. For all ewes, there is significant effect of the high CS 3.5 treatment on number of lambs born alive per ewe and at the end of birthing that carries through to marking and weaning. Where ewes were scanned as carrying a single lamb there appears to be an effect of CS 3.0 treatment reducing the number of lambs born alive at birth. For ewes scanned as carrying multiple lambs the higher CS treatment (CS3.5) results in more lambs alive per ewe at marking and weaning. The effect is consistent with more multiple lambs being alive at the end of birthing but the effect is not quite significant at this point in time for multiple scanned ewes(p=0.065).

Table 7. Effect of condition score (CS) treatment on measurements related to lambing numbers (p values in bold type are significant).

	CS 2.5	CS 3.0	CS 3.5	sed	P value
Number of dams/progeny per ewe scanned					
Dams at birth	0.98	0.98	0.99	0.011	0.59[a]
Dams with lamb	0.97	0.96	0.98	0.016	0.53[a]
Lambs born[b]	1.51	1.51	1.57	0.031	0.098
Lambs born alive[b]	1.47	1.45	1.54	0.027	**0.014**
Lambs alive at end of birthing	1.40	1.39	1.50	0.029	**0.0042**
Lambs alive at marking	1.37	1.37	1.47	0.032	**0.013**
Lambs alive at weaning	1.36	1.36	1.45	0.026	**0.0046**
Number of dams/progeny per single ewe scanned					
Dams at birth	1.00	1.00	0.99	0.008	1.00[a]
Dams with lamb	1.00	0.97	0.98	0.021	0.32[a]
Lambs born[bc]	1.01	0.99	1.02	0.025	0.48
Lambs born alive[bc]	0.99	0.93	0.99	0.025	**0.045**
Lambs alive at end of birthing[c]	0.99	0.92	0.98	0.025	**0.026[d]**
Lambs alive at marking	0.97	0.92	0.95	0.030	0.26
Lambs alive at weaning	0.97	0.92	0.93	0.029	0.21
Number of dams/progeny per multiple ewe scanned					
Dams at birth	0.96	0.97	0.99	0.019	0.19[a]
Dams with lamb	0.94	0.96	0.98	0.026	0.25[a]
Lambs born[bc]	1.91	1.92	1.97	0.053	0.50
Lambs born alive[bc]	1.85	1.87	1.94	0.056	0.24
Lambs alive at end of birthing[c]	1.73	1.77	1.89	0.062	0.065
Lambs alive at marking	1.69	1.74	1.86	0.062	**0.045**
Lambs alive at weaning	1.68	1.72	1.85	0.053	**0.014**

[a] Using permutation test
[b] And observed. Some births may never have been observed.
[c] These numbers do not include a few lambs with unknown scan parity.
[d] The significance is weak and isolated, and is associated with a low sed. This apparent effect may well be chance.

Autopsy data

As indicated in the lambing numbers above the survival of lambs born in this experiment was very high and thus the number of lambs that died and were autopsied (n=62) was small representing only 6.3% of all lambs tagged at birth (n=990). These small numbers present issues for statistical analysis and comparisons between autopsy categories in assessing differences in the likely cause of death between treatments. The information that follows provides a summary of the amalgamated raw autopsy data based on the autopsy method and death categories of Holst (2004). The proportion of lambs in each death category are presented in Table 8 below. Dystocia categories represented 45.1% of all dead lambs and starvation mismothering and exposure (SME) accounted for 24.2%. The next largest category was category 8 infection at 12.9%. Primary predation only accounted for 3.2% of deaths. Lambs in the dystocia categories had an average birth weight of 5.5kg compared to 4.2kg in the SME, while lambs that lived had an average birth weight of 5.18kg.

Table 8. The proportion of dead lambs in each death category autopsied and assessed at lambing according to Holst (2004).

Death Category	Death Category Description	Number of Lambs	Average Birth Weight (kg)	Percentage of all lambs born	Percentage of all dead lambs
1	Dystocia (a)	18	5.6	1.8	29.0
2	Dystocia (b)	3	6.5	0.3	4.8
3	Dystocia (c)	7	4.8	0.7	11.3
4	Starvation/ Mismothering	13	4.4	1.3	21.0
5	Primary Predation	2	6.4	0.2	3.2
6	Premature or dead 'in utero'	3	3.3	0.3	4.8
7	Primary Exposure	2	3.0	0.2	3.2
8	Infection	8	4.6	0.8	12.9
9	Undiagnosed	5	3.3	0.5	8.1
10	Misadventure	1	5.2	0.1	1.6

The proportion of dead lambs for each CS treatment were 35.5%, 40.3% and 24.2% for the CS 2.5, CS 3.0 and CS 3.5 treatments respectively. This is consistent with the observed trend for a greater number of lambs surviving to weaning for lambs born to CS 3.5 treatment ewes. Of the lambs that died it appears that CS3.0 lambs had a higher proportion of dystocia related deaths (Table 9) and this would be consistent with the higher average birth weight of this treatment (Table 10), although care needs to be taken with this interpretation due to the small number of dead lambs involved.

Table 9. The proportion of dead lambs assessed into dystocia and starvation/mismothering/exposure categories for each condition score treatment.

CS Treatment	Proportion of lambs in dystocia categories (1-3)	Proportion of lambs in starvation/mismothering & primary exposure categories(4 & 7)
2.5	45.5	18.2
3	52.0	28.0
3.5	33.3	26.7

As expected lambs that were single lambs or male lambs had a greater proportion of dead lambs in the dystocia categories and this was also consistent with heavier birth weights for these lambs. There were also more dead male lambs than dead females (56.5% vs. 43.3%).

The effect of condition score treatment on measures related to birth weight

The results for birth weight related measurements are reported in table 10. There is a significant effect of CS treatment on the birth weight of all lambs and those born alive. Lambs born to CS 2.5 treatment were on average 230g lighter than those born under the CS 3.0 treatment, whilst lambs born to the CS 3.5 treatment were intermediate and not significantly different to either the CS 3.0 or CS 2.5 treatments. The same trends in birth weight of lambs are evident in both single scanned and twin scanned dams but the effects were not significant (p= 0.096 and p=0.088 respectively).

The trends in birth weight data compared to CS treatment are also repeated for male and female lambs but only significant in male lambs (p=0.036) where male lambs born to the CS 3.0 treatment ewes were 350g heavier than those born to CS 2.5 treatment. The difference in female lambs was only 90g and not significant (p=0.70)

Table 10 Effect of condition score (CS) treatment on measurements related to birth weight of lambs. (p values in bold type are significant).

	CS 2.5	**CS 3.0**	**CS 3.5**	**sed**	**P value**
Average birth weight of lambs observed					
All lambs (alive and dead)	5.06	5.29	5.13	0.087	**0.046**
Lambs born alive	5.05	5.29	5.13	0.090	**0.048**
Lambs alive at end of birthing	5.10	5.32	5.15	0.089	0.070
Average birth weight of lambs observed from single scan dams[a]					
All lambs (alive and dead)	6.01	6.16	5.90	0.110	0.096
Lambs born alive	5.97	6.13	5.86	0.131	0.15
Lambs alive at end of birthing	5.97	6.15	5.85	0.125	0.091
Average birth weight of lambs observed from multiple scan dams[a]					
All lambs (alive and dead)	4.65	4.93	4.84	0.115	0.088
Lambs born alive	4.66	4.95	4.84	0.121	0.090
Lambs alive at end of birthing	4.70	4.96	4.86	0.118	0.12
Average birth weight of male lambs observed					
All lambs (alive and dead)	5.17	5.52	5.28	0.124	**0.036**
Lambs born alive	5.14	5.48	5.25	0.125	**0.049**
Lambs alive at end of birthing	5.25	5.50	5.27	0.115	0.089
Average birth weight of female lambs observed					
All lambs (alive and dead)	4.95	5.04	4.99	0.100	0.70
Lambs born alive	4.96	5.07	5.01	0.090	0.46
Lambs alive at end of birthing	4.96	5.10	5.03	0.097	0.39

[a] These numbers do not include a few lambs with unknown scan parity.

The effect of condition score treatment on percentage of male lambs

Table 11 presents data on the percentage of male lambs that were born to ewes from each CS treatment. There appears to be a trend that the percentage of lambs that are male is higher in the CS 3.0 treatment than the CS 2.5 treatment and this is significant for lambs born alive and alive at the end of birthing. Again the CS3.5 treatment values are intermediate between the other two CS treatments.

Table 11. Effect of condition score (CS) treatment on percentage of lambs that are male. (p values in bold type are significant).

	CS 2.5	CS 3.0	CS 3.5	sed	P value
Percentage male of lambs observed					
All lambs (alive and dead)[b]	47.6	53.4	50.4	2.24	0.063
Lambs born alive[b]	46.9	53.7	50.0	2.43	**0.045**
Lambs alive at end of birthing	46.2	53.7	49.9	2.58	**0.040**
Percentage male of lambs observed from single scan dams[a]					
All lambs (alive and dead)	42.3	52.9	44.9	6.10	0.24
Lambs born alive	40.9	51.0	43.2	5.98	0.25
Lambs alive at end of birthing	40.9	51.0	43.2	5.98	0.25
Percentage male of lambs observed from multiple scan dams[a]					
All lambs (alive and dead)[b]	49.6	53.4	51.9	3.28	0.53
Lambs born alive[b]	49.4	54.5	51.6	3.51	0.37
Lambs alive at end of birthing	48.2	54.3	51.5	3.50	0.25

[a] These numbers do not include a few lambs with unknown scan parity.
[b] A small number of lambs have unknown sex. In these cases the percentage is approximated by coding unknown lambs as 50% male and 50% female.

Lamb growth – Lambing to weaning

Effect of Condition Score treatment on live weight and live weight change from birth to weaning

Table 12 presents results of live weight from birth to weaning for each CS treatment. The results indicate that CS 3.0 treatment consistently resulted in the highest live weight lambs at marking and weaning, while CS2.5 treatment was the lowest and CS3.5 treatment intermediate. CS2.5 lambs were 0.9kg and 1.8kg lighter than CS 3.0 treatment lambs at marking and weaning. The trends in live weight response to CS were also reflected in lambs born to single and twin scanned ewes all be it that lambs born to single scanned ewes were heavier (~6-7kg) than those born to twin scanned ewes.

Live weight change from birth to weaning is presented in Table 13. With the exception of a few weigh points between birth and weaning this data follows the same trends as that for live weight with CS 2.5 lambs gaining the least live weight and CS 3.0 the most with CS 3.5 treatment lambs being intermediate in live weight gain. The effect of condition score treatment on the average relative live weight growth from birth to weaning is presented in Table 14. Aside from some effects occurring around the movement of lambs from the EverGraze pastures to those used immediately prior to weaning there is no significant differences in relative live weight growth between birth and marking, marking to weaning and the entire period from birth to weaning.

Table 12. Effect of condition score (CS) treatment, of lambs surviving to end of birth period, on live weight from birth to weaning. (p values in bold type are significant).

	CS 2.5	CS 3.0	CS 3.5	sed	P value
Live weight (kg)					
Birth weight of lambs alive at end of birthing	5.1	5.3	5.1	0.09	0.070
Marking	15.7	16.6	16.3	0.30	**0.031**
Left Evergraze paddocks (late Nov)	26.6	28.3	27.0	0.50	**0.013**
Weaning	28.9	30.7	29.8	0.52	**0.0086**
Live weight (kg) from single scan dams[a]					
Birth weight of lambs alive at end of birthing	6.0	6.2	5.9	0.13	0.091
Marking	18.8	19.8	18.9	0.45	0.099
Left Evergraze paddocks (late Nov)	31.0	32.7	30.8	0.65	**0.023**
Weaning	33.5	35.9	34.0	0.81	**0.031**
Live weight (kg) from multiple scan dams[a]					
Birth weight of lambs alive at end of birthing	4.7	5.0	4.9	0.12	0.12
Marking	14.2	15.2	15.3	0.39	**0.028**
Left Evergraze paddocks (late Nov)	24.5	26.4	25.7	0.56	**0.020**
Weaning	26.7	28.5	28.2	0.57	**0.010**

[a] These numbers do not include one lamb with unknown scan parity.

Table 13. Effect of condition score (CS) treatment on live weight change from birth to weaning. (p values in bold type are significant).

	CS 2.5	CS 3.0	CS 3.5	sed	P value
Live weight change (kg)					
Birth to marking	10.6	11.2	11.1	0.27	0.059
Marking to leaving Evergraze paddocks	10.9	11.7	10.7	0.26	**0.0055**
Leaving Evergraze paddocks to Weaning	2.2	2.5	2.7	0.18	**0.038**
Marking to weaning	13.1	14.2	13.5	0.27	**0.0059**
Birth to weaning	23.7	25.4	24.6	0.48	**0.011**
Live weight change (kg) from single scan dams[a]					
Birth to marking	12.8	13.6	13.0	0.41	0.14
Marking to leaving Evergraze paddocks	12.3	13.0	11.8	0.36	**0.023**
Leaving Evergraze paddocks to Weaning	2.5	3.1	3.2	0.30	0.063
Marking to weaning	14.7	16.1	15.0	0.49	**0.038**
Birth to weaning	27.5	29.8	28.1	0.83	**0.046**
Live weight change (kg) from multiple scan dams[a]					
Birth to marking	9.5	10.2	10.4	0.34	**0.041**
Marking to leaving Evergraze paddocks	10.3	11.2	10.3	0.29	**0.019**
Leaving Evergraze paddocks to Weaning	2.1	2.2	2.5	0.20	0.092
Marking to weaning	12.4	13.3	12.9	0.29	**0.020**
Birth to weaning	21.9	23.6	23.3	0.53	**0.014**

[a] These numbers do not include one lamb with unknown scan parity.

Table 14. Effect of condition score (CS) treatment average relative live growth from birth to weaning. (p values in bold type are significant).

	CS 2.5	CS 3.0	CS 3.5	sed	P value
Average relative live weight change (mg/kg per day)					
Birth to marking	34.4	34.5	34.4	0.47	0.99
Marking to leaving Evergraze paddocks	14.3	14.4	13.7	0.22	**0.0084**
Leaving Evergraze paddocks to Weaning	9.8	10.3	12.1	1.00	**0.038**
Marking to weaning	13.5	13.7	13.4	0.18	0.20
Birth to weaning	22.2	22.4	22.3	0.20	0.67
Average relative live weight change (mg/kg per day) from single scan dams[a]					
Birth to marking	35.9	36.3	35.2	0.74	0.32
Marking to leaving Evergraze paddocks	13.5	13.5	13.1	0.30	0.29
Leaving Evergraze paddocks to Weaning	9.6	11.6	12.5	1.05	**0.045**
Marking to weaning	12.8	13.2	12.9	0.26	0.37
Birth to weaning	22.3	22.8	22.4	0.36	0.40
Average relative live weight change (mg/kg per day) from multiple scan dams[a]					
Birth to marking	33.8	33.7	34.1	0.59	0.70
Marking to leaving Evergraze paddocks	14.8	14.8	13.9	0.36	**0.047**
Leaving Evergraze paddocks to Weaning	9.9	9.8	11.9	1.22	0.18
Marking to weaning	13.9	13.9	13.5	0.29	0.38
Birth to weaning	22.2	22.3	22.3	0.29	0.92

[a] These numbers do not include one lamb with unknown scan parity.

Effect of Condition Score treatment on eye muscle and fat depths of lambs at weaning

Table 15 presents data on ultrasound scanned muscle and fat depth measured at weaning. This data shows trends similar to the live weight data where those lambs born to the CS 2.5 treatment have the least fat and muscle depth and those born to CS 3.0 have the most. Again CS 3.5 lambs are intermediate. However the effects for eye muscle depth are only significant in multiple scanned lambs, whilst effects on fat depth are significant in all lambs.

Table 15. Effect of condition score (CS) treatment eye muscle depth (EMD) and fat depth of lambs at weaning. (p values in bold type are significant).

	CS 2.5	CS 3.0	CS 3.5	sed	P value
EMD at weaning					
All lambs	22.1	23.2	22.7	0.43	0.064
Single scan lambs[a]	25.8	26.7	25.9	0.59	0.30
Multiple scan lambs[a]	20.4	21.7	21.5	0.44	**0.023**
Fat Depth at weaning					
All lambs	2.14	2.37	2.21	0.085	**0.047**
Single scan lambs[a]	3.08	3.37	3.09	0.154	0.14
Multiple scan lambs[a]	1.71	1.94	1.88	0.091	0.065

[a] These numbers do not include one lamb with unknown scan parity.

Gestational condition score effects on post-weaning body composition of lambs
Dual X-ray absorptiometry was conducted on the 7th and 18th of January after weaning but prior to lambs entering the feedlot finishing phase. Table 16 shows the body composition of lambs based on a DXA measured percentage of lean, fat and ash. Values are also shown after adjustment for liveweight effects of the CS treatment. The table shows that differences in lean and fat appear to be mostly associated with differences in liveweight produced by the CS treatment during pregnancy. There is also evidence that the CS 2.5 lambs have slightly higher ash content at this measurement conducted while the lambs were still grazing. This effect appears to be maintained after adjusting for live weight (p=0.087, Table 16).

Table 16. Effect of condition score (CS) treatment of dam on composition as assessed by DXA during grazing period, for multiple born, male lamb progeny. In results adjusted for live weight, the range in sed values for comparing different pairs of treatment is presented.

Body composition by Dual X-ray Absorptiometry	CS 2.5	CS 3.0	CS 3.5	sed	P value
Lean (%)	81.8	81.2	81.5	0.25	**0.050**
Lean (%) adjusted for live weight	81.5	81.5	81.4	0.24-0.36	0.84
Fat (%)	14.4	14.9	14.8	0.24	0.14
Fat (%) adjusted for live weight	14.7	14.6	14.8	0.25-0.38	0.60
Ash (%)	4.1	3.8	3.9	0.06	**0.0018**
Ash (%) adjusted for live weight	4.0	3.9	3.9	0.06-0.09	0.087

Feedlot finishing
The feedlot induction period was 12, 15 and 22 days depending on the staging of the AI group/block feedlot entry for blocks 1, 2 and 3 respectively. The induction phase length was timed to meet slaughter dates and allow for the same length of finishing phase for each AI group. At the end of induction phase the average weight was 35.4kg with a growth rate of 246g/day. However, the growth rates during this period were different for each AI group/block due to the staggered feedlot entry and length of the induction period. Group 1 grew at 18.3g/day entering the finishing phase at 33.2kg. Group 2 grew at 299g/day entering the finishing phase at 34.1kg and Group 4 grew at 429g/day and entering the finishing phase at 38.8kg.

The average starting weight for the feedlot finishing phase was 35.4kg and the average finishing weight was 53.3kg (ranging from 34.6kg and 71.6kg). The average growth rate was 326g/day ranging from (69g/day to 509g/day). The final pre-slaughter weights averaged 51.8kg (ranging from 33kg to 69.4kg).

Feed conversion ratio
Table 17 presents the mean data for pens of lambs fed the different finishing diets during the feedlot finishing phase of the experiment. Note that as lambs were not fed individually or measured individually these feed intake values have been calculated based on the amount of pellets offered and the residual feed left in the sheep feeders at the end of the experiment. Each mean value for each ration represents the mean across three pens (based on the 3 blocks/AI groups). The data are also only for the period of *ad libitum* feedlot feeding in the experiment. No attempt has been made to correct for spillage and wastage of pellets by lambs from the feeders.

These results indicate the lambs fed the moderate ME, high crude protein, pelleted ration consumed around 50% (or around 0.8kg/head/day) more than the other two diets over the course of the finishing period under *ad libitum* feeding. This is substantial difference in the amount of feed consumed by lambs during the finishing period. When this data is compared to the average live weight gain for lambs on these diets the feed conversion ratio is markedly poorer for lambs fed the moderate ME and high CP diet, despite higher growth rate (~50g/day greater) and overall liveweight gain (~3kg greater) (Table 17). Using the cost of pellets for each of the rations purchased for the study the difference in performance on moderate ME, high crude protein, results in extra $20/head (~$0.50/kg liveweight gain) in feed costs compared to the other two rations, driven by the higher total consumption and high FCR.

It is worth noting that while the trends in live weight gain and feed intake predicted through GrazFeed based on measured ME and CP was in broad agreement with the values for the for the first two diets in Table 3, the intake and growth rate of lambs consuming the moderate ME and High CP diet was much greater than predicted. This may signify that lambs may be able to use extra crude protein as an energy source and consume more feed to increase growth rate when diets have lower ME but higher CP. The difference in performance of this ration may however also be due to differences in the key ingredients used to formulate each pellet ration.

Table 17. The liveweight, liveweight gain, growth rate, feed intake and feed conversion ratio of groups of lambs fed three different rations *ad libitum* in the feedlot.

Feedlot Ration	Starting liveweight (kg)	Finished liveweight (kg)	Weight Gain (kg)	Growth rate (g/day)	Feed intake (kg/hd/day)	Feed intake per animal (kg/head)	FCR (kg fed/kg gain)
High ME High CP	35.3	52.4	17.1 [a]	311 [a]	1.55 [a]	83.9 [a]	4.9 [a]
High ME Moderate CP	36.0	52.5	16.6 [a]	301 [a]	1.78 [a]	96.1 [a]	5.9 [b]
Moderate ME High CP	34.7	55.0	20.2 [b]	367 [b]	2.66 [b]	143.5 [b]	7.2 [b]
LSD ($p<0.05$)	2.6	2.8	1.9	35.1	0.55	29.8	1.3

Values with different superscripts are significantly different ($p<0.05$)

The impacts of gestational condition score on the prime lamb

Effects of ewe condition score treatment during finishing

The CS 2.5 treatment, multiple lambs were lighter than similar lambs from the other 2 pregnancy treatments both at entry (by 1.1 to 2.6kg) and exit (by 1.8 to 2.6kg) to the feedlot (Table 18). However, the change in live weight during the feed lotting period was similar between the 3 pregnancy treatment on both absolute and relative basis. Although, CS 3.0 treatment lambs had slightly lower relative weight gain.

There is clear evidence that the multiple wether progeny of the ewes having declining condition (CS 2.5) during pregnancy have a higher chemical (DXA) lean (%), and a lower chemical (DXA) fat (%) at mid-feedlot (Table 18). While there appeared to be a similar trend present in single lambs the experiment had insufficient precision to determine whether the effect occurred in single lambs, or not. The effects on lean and fat percentage are also still present after adjusting for the liveweight of the animal which was also affected by the low CS 2.5 treatment. The DXA measured ash content of multiple lambs was also higher in CS 2.5 treatment lambs and remained so after adjusting for the liveweight.

There is also evidence that the multiple wether progeny of the ewes having declining condition (CS 2.5) during pregnancy have a lower ultrasound measured EMD (by 0.6 to 1.4mm) and a lower fat depth (by 0.4mm) than the other CS treatments (Table 19). However, a large part of this effect can be explained by the effect of CS 2.5 on live weight of lambs. This was particularly the case for EMD where the effect becomes not significant.

Table 18. The feedlot entry, exit, liveweight gain and mid-feedlot body composition of lambs from different ewe gestational condition score treatments as measured during the feedlot finishing phase. (Values in bold indicate a significant effect)

	Condition Score Treatment			sed	P Value
	CS 2.5	**CS 3.0**	**CS 3.5**		
Liveweight					
Feedlot entry weight (kg)					
All (Singles and Multiples)	29.4	31.9	29.8	0.69	**0.0063**
Birth multiples	27.6	30.2	28.7	0.76	**0.017**
Birth singles	34.1	35.9	35.1	0.97	0.19
Feedlot exit weight (kg)					
All (Singles and Multiples)	52.1	54.1	53.0	0.87	0.12
Birth multiples	49.8	52.4	51.6	0.74	**0.011**
Birth singles	57.2	57.8	58.1	1.51	0.82
Feedlot weight gain (kg)					
All (Singles and Multiples)	22.6	22.2	23.1	0.62	0.39
Birth multiples	22.2	22.3	22.8	0.56	0.52
Birth singles	23.1	21.9	23.1	1.19	0.52
Feedlot relative weight gain (% per day)					
All (Singles and Multiples)	0.81	0.75	0.82	0.024	**0.037**
Birth multiples	0.84	0.79	0.83	0.027	0.16
Birth singles	0.73	0.67	0.71	0.035	0.26
DXA (mid-feedlot)					
Adjusted lean (%)					
All (Singles and Multiples)	78.0	77.0	77.2	0.31	**0.030**
Birth multiples	78.3	77.4	77.6	0.22	**0.0065**
Birth singles	77.0	76.4	76.0	0.45	0.19
Adjusted lean (%) adjusted for live weight					
All (Singles and Multiples)	77.8	77.2	77.1	0.28-0.33	0.083
Birth multiples	78.3	77.4	77.6	0.23-0.27	**0.031**
Birth singles	76.8	76.6	76.0	0.48-0.66	0.24
Adjusted fat (%)					
All (Singles and Multiples)	17.8	18.8	18.7	0.39	0.060
Birth multiples	17.6	18.5	18.3	0.28	**0.029**
Birth singles	18.6	19.0	19.8	0.63	0.21
Adjusted fat (%)adjusted for live weight					
All (Singles and Multiples)	17.9	18.6	18.8	0.38-0.46	0.13
Birth multiples	17.6	18.4	18.4	0.30-0.36	0.086
Birth singles	18.6	18.9	19.8	0.69-0.95	0.26
Adjusted ash (%)					
All (Singles and Multiples)	3.3	3.2	3.1	0.03	**0.0029**
Birth multiples	3.4	3.3	3.2	0.03	**0.0016**
Birth singles	3.1	3.1	3.0	0.05	0.13
Adjusted ash (%) adjusted for live weight					
All (Singles and Multiples)	3.3	3.2	3.1	0.03	**0.0032**
Birth multiples	3.4	3.2	3.2	0.034-0.040	**0.0041**
Birth singles	3.0	3.1	2.9	0.05-0.06	**0.047**

Table 19 The fat and muscle depth of lambs from different ewe gestational condition score treatments assessed by ultrasound scanning one week prior to slaughter at the end of the feedlot finishing phase. (Values in bold indicate a significant effect)

Measurement	**Condition Score Treatment**				
	CS 2.5	**CS 3.0**	**CS 3.5**	**sed**	**P Value**
Ultrasound (late feedlot)					
Eye muscle depth					
All (Singles and Multiples)	32.9	34.3	33.5	0.36	**0.0088**
Birth multiples	32.3	33.9	33.2	0.39	**0.0051**
Birth singles	34.7	35.2	35.0	0.47	0.67
Fat depth					
All (Singles and Multiples)	4.56	4.82	4.74	0.128	0.17
Birth multiples	4.32	4.70	4.74	0.138	**0.017**
Birth singles	5.17	5.11	4.90	0.165	0.27
Ultrasound (late feedlot) adjusted for live weight					
Eye muscle depth					
All (Singles and Multiples)	33.2	33.9	33.5	0.28-0.32	0.11
Birth multiples	32.8	33.6	33.1	0.34-0.45	0.26
Birth singles	34.8	35.2	34.9	0.39-0.40	0.68
Fat depth					
All (Singles and Multiples)	4.65	4.74	4.74	0.118-0.135	0.72
Birth multiples	4.37	4.66	4.73	0.147-0.197	**0.037**
Birth singles	5.12	5.16	4.91	0.167-0.184	0.28

Effects on carcass weight and composition characteristics

Results presented in Tables 20 - 23 indicate relatively few statistically significant differences in carcass weight, body composition and abattoir measurements between the gestational condition score treatments.

For multiple lambs, the final empty liveweight prior to slaughter was 2.2 to 2.7kg lower for CS 2.5 treatment lambs than the CS 3.0 and CS 3.5 derived lambs (Table 20, $p<0.05$). CS 2.5 treatment multiple lambs also had a lower carcass weight by 0.9 to 1.4kg. There was insufficient precision in the experiment to detect effects on single lambs.

Contrary to the hypothesis that lower gestational condition score of ewes would make their lambs fatter at slaughter this study shows that lambs born to CS 2.5 treatment ewes were lower in chemical fat and had greater lean (%) by approximately 1% unit than CS 3.0 and 3.5 treatment lambs based on DXA scanned values of adjusted lean and fat in both analyses ($p<0.05$). This trend was very evident in multiples (Table 21) but not in singles as there was insufficient precision to draw a conclusion on the latter.

These effects on leanness and fatness were still present after the data is adjusted for the carcass weight effects of CS 2.5 treatment.

Table 20. Effect of condition score (CS) target treatment on pre-slaughter weight, dressing percentage and hot carcass weight. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

	CS Group			**sed**	**P Value**
	CS 2.5	**CS 3.0**	**CS 3.5**		
Weight					
Final empty body weight (kg)					
All (Singles and Multiples)	50.6	52.6	51.6	0.84	0.093
Scanned multiples	48.5	51.0	50.5	0.79	**0.016**
Birth multiples	48.3	51.0	50.5	0.79	**0.012**
Scanned singles	55.8	56.2	55.7	1.26	0.92
Birth singles	55.9	56.1	56.5	1.37	0.90
Dressing Percentage (%)					
All (Singles and Multiples)	49.2	49.4	49.2	0.22	0.82
Scanned multiples	49.1	49.2	49.0	0.26	0.75
Birth multiples	49.1	49.2	49.0	0.26	0.76
Scanned singles	51.1	49.9	50.2	1.04	0.51
Birth singles	51.2	49.9	50.3	1.07	0.49
Hot carcass weight (kg)					
All (Singles and Multiples)	25.0	26.0	25.4	0.47	0.15
Scanned multiples	23.8	25.1	24.6	0.42	**0.028**
Birth multiples	23.7	25.1	24.6	0.44	**0.025**
Scanned singles	27.9	27.8	28.0	0.83	0.98
Birth singles	27.8	27.8	28.5	0.87	0.67

There was also evidence that the multiple wether progeny of the ewes having declining condition (CS 2.5) during pregnancy have a lower C Fat and GR 12 Fat (%) (Table 23). This is evidence that the effects observed in DXA measurements are at least partially related to differences in inter-muscular fat deposition. After adjusting for the impact of liveweight the significance of the effect on both these measures was reduced (Table 23) indicating that these measures were at least partially related to the carcass weight of CS 2.5 lambs.

There were no significant effects of CS treatment on carcass measures eye muscle width, length or area.

There was insufficient precision from this study and analysis, to conclude any effects of CS treatment on the lean meat yield parameters based on either full or partial bone out data presented in Table 22. However, one point of interest may be the higher bone yield observed in CS 2.5 multiples under full bone out and a close to significant trend towards a higher leg bone yield in the partial bone out data (p=0.068 to 0.072).

Table 21. Effect of condition score (CS) target treatment on DXA assessed carcass composition. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Carcass DXA	**CS 2.5**	**CS 3.0**	**CS 3.5**	**sed**	**P Value**
Adjusted lean (%)					
All (Singles and Multiples)	63.3	62.4	62.1	0.36	**0.015**
Scanned multiples	63.8	62.7	62.4	0.40	**0.0088**
Birth multiples	63.9	62.7	62.4	0.36	**0.0030**
Scanned singles	62.1	62.1	61.7	0.69	0.80
Birth singles	61.9	62.0	61.5	0.61	0.69
Adjusted lean (%) adjusted for hot carcass weight					
All (Singles and Multiples)	63.1	62.6	62.1	0.34-0.38	**0.032**
Scanned multiples	63.8	62.7	62.4	0.43-0.54	**0.045**
Birth multiples	63.9	62.7	62.4	0.40-0.50	**0.014**
Scanned singles	62.1	62.1	61.7	0.70	0.83
Birth singles	61.9	62.0	61.5	0.63-0.65	0.74
Adjusted fat (%)					
All (Singles and Multiples)	35.1	36.0	36.5	0.44	**0.019**
Scanned multiples	34.7	35.8	36.2	0.54	**0.029**
Birth multiples	34.6	35.8	36.3	0.52	**0.019**
Scanned singles	35.8	36.4	36.4	1.15	0.85
Birth singles	36.1	35.9	36.6	0.79	0.69
Adjusted fat (%)adjusted for hot carcass weight					
All (Singles and Multiples)	35.1	35.8	36.5	0.46-0.52	**0.037**
Scanned multiples	34.6	35.9	36.3	0.58-0.73	**0.060**
Birth multiples	34.4	36.0	36.3	0.55-0.69	**0.026**
Scanned singles	35.8	36.4	36.4	1.20	0.86
Birth singles	36.1	35.8	36.7	0.79-0.81	0.58
Adjusted ash (%)					
All (Singles and Multiples)	4.5	4.4	4.4	0.05	0.18
Scanned multiples	4.5	4.4	4.4	0.08	0.31
Birth multiples	4.5	4.4	4.4	0.08	0.28
Scanned singles	4.3	4.4	4.2	0.10	0.54
Birth singles	4.3	4.4	4.3	0.09	0.61

Table 22. Effect of condition score (CS) target treatment on lean meat yield measurements by full bone out and partial bone out. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Carcass Dissection	**CS 2.5**	**CS 3.0**	**CS 3.5**	**sed**	**P Value**
Full bone out					
Meat Yield (%)					
All (Singles and Multiples)	57.3	56.0	56.4	0.86	0.36
Birth multiples	57.4	56.0	56.6	1.06	0.42
Fat (%)					
All (Singles and Multiples)	17.8	19.0	17.8	0.92	0.33
Birth multiples	16.0	19.1	17.5	1.10	0.053
Bone (%)					
All (Singles and Multiples)	25.1	25.1	26.0	0.61	0.40
Birth multiples	26.9	25.1	26.3	0.44	**0.0053**
Birth multiples (adjusted for hot carcass weight)	26.6	25.3	26.2	0.45-0.56	0.079
Partial bone out					
Gardiner predicted meat yield (%)					
All (Singles and Multiples)	60.8	60.5	60.2	0.35	0.25
Scanned multiples	61.4	60.9	60.5	0.39	0.14
Birth multiples	61.4	60.9	60.5	0.38	0.11
Three muscle yield (loin, topside, round, %)					
All (Singles and Multiples)	12.5	12.4	12.3	0.11	0.23
Scanned multiples	12.6	12.5	12.3	0.17	0.41
Birth multiples	12.6	12.5	12.3	0.17	0.40
Topside yield (%)					
All (Singles and Multiples)	5.1	5.1	5.0	0.07	0.49
Scanned multiples	5.2	5.1	5.1	0.09	0.53
Birth multiples	5.2	5.1	5.1	0.09	0.57
Round yield (%)					
All (Singles and Multiples)	3.9	3.8	3.8	0.04	0.22
Scanned multiples	3.9	3.9	3.8	0.05	0.70
Birth multiples	3.9	3.9	3.8	0.04	0.59
Loin yield (%)					
All (Singles and Multiples)	3.5	3.5	3.4	0.05	0.58
Scanned multiples	3.5	3.5	3.4	0.08	0.55
Birth multiples	3.5	3.5	3.4	0.08	0.55
Leg bone yield (%)					
All (Singles and Multiples)	4.3	4.2	4.2	0.04	0.072
Scanned multiples	4.3	4.2	4.2	0.05	0.077
Birth multiples	4.3	4.2	4.2	0.06	0.068
Two bone yield (leg, H)					
All (Singles and Multiples)	7.8	7.7	7.7	0.10	0.78
Scanned multiples	7.8	7.7	7.8	0.12	0.60
Birth multiples	7.9	7.7	7.8	0.12	0.52

Table 23. Effect of condition score (CS) target treatment on abattoir measures fat and muscle. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Abattoir	**CS 2.5**	**CS 3.0**	**CS 3.5**	**sed**	**P Value**
Carcass fat score					
All (Singles and Multiples)	3.3	3.4	3.3	0.09	0.41
Scanned multiples	3.2	3.3	3.3	0.12	0.42
Birth multiples	3.2	3.3	3.3	0.12	0.37
GR 12th					
All (Singles and Multiples)	15.5	16.2	16.1	0.46	0.29
Scanned multiples	14.7	16.2	15.7	0.41	**0.0083**
Birth multiples	14.6	16.2	15.7	0.39	**0.0047**
GR 12th adjusted for hot carcass weight					
All (Singles and Multiples)	15.8	15.9	16.1	0.40-0.46	0.68
Scanned multiples	14.8	16.1	15.7	0.44-0.55	0.093
Birth multiples	14.8	16.1	15.7	0.41-0.52	0.086
GR 5th					
All (Singles and Multiples)	6.0	6.3	6.4	0.33	0.44
Scanned multiples	5.8	6.1	6.5	0.34	0.13
Birth multiples	5.7	6.1	6.5	0.35	0.14
C Fat					
All (Singles and Multiples)	5.0	5.5	5.4	0.32	0.24
Scanned multiples	4.5	5.4	5.1	0.26	**0.021**
Birth multiples	4.5	5.4	5.1	0.25	**0.013**
C Fat adjusted for hot carcass weight					
All (Singles and Multiples)	5.1	5.3	5.4	0.29-0.33	0.24
Scanned multiples	4.7	5.2	5.0	0.27-0.33	0.28
Birth multiples	4.6	5.3	5.1	0.26-0.33	0.17
EMA (L)					
All (Singles and Multiples)	65.7	65.9	66.1	0.47	0.65
Scanned multiples	65.1	65.5	65.5	0.61	0.77
Birth multiples	65.1	65.5	65.5	0.62	0.71
EMA (W)					
All (Singles and Multiples)	32.2	33.2	32.6	0.49	0.20
Scanned multiples	31.6	32.9	32.2	0.66	0.23
Birth multiples	31.7	32.9	32.2	0.69	0.25
EMA (Calculated)					
All (Singles and Multiples)	17.0	17.6	17.3	0.33	0.26
Scanned multiples	16.5	17.3	16.9	0.43	0.21
Birth multiples	16.5	17.4	16.9	0.45	0.22

Measurements of intramuscular fat were not significantly different between CS treatments (Table 24) but there appears to be a trend in the data with IMF values for multiples and singles being lower. The statistical comparison was also improved by adjustment for carcass weight and the trend in IMF was maintained. This suggests that intramuscular fat cannot be ruled out as at least a partial contributor to the differences observed in DXA lean and fat percentage.

Table 24. Effect of condition score (CS) target treatment on Intramuscular fat (IMF). The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Intramuscular Fat	CS 2.5	CS 3.0	CS 3.5	sed	P Value
IMF					
All (Singles and Multiples)	3.20	3.33	3.48	0.116	0.10
Scanned multiples	3.17	3.32	3.45	0.132	0.15
Birth multiples	3.16	3.33	3.41	0.130	0.19
Scanned singles	3.26	3.45	3.73	0.287	0.29
Birth singles	3.29	3.45	3.78	0.297	0.29
IMF adjusted for hot carcass weight					
All (Singles and Multiples)	3.20	3.34	3.47	0.124-0.139	0.12
Scanned multiples	3.10	3.38	3.65	0.136-0.170	0.090
Birth multiples	3.10	3.38	3.42	0.136-0.171	0.13
Scanned singles	3.26	3.44	3.75	0.257	0.20
Birth singles	3.25	3.41	3.86	0.259-0.265	0.097

Effects of gestational condition score on fresh meat colour values and shear force in lambs

There were no significant effects of CS treatment during pregnancy on the fresh meat colour *L* or *a* values but CS2.5 treatment multiple lambs had a lower (by 0.2 to 0.3) *b* value than the other CS treatments (Table 25). This indicates that these lambs had fresh meat colour that was less yellow than the higher CS treatments.

There was no significant effect of CS treatment on shear force values measured at day five post slaughter with CS2.5 birth multiples even though the shear forces was 1.6N higher (p=0.12; Table 25).

Table 25. Effect of condition score (CS) treatment on the ewe on fresh meat colour values and shear force at day 5 of the lamb.

	CS Group			sed	P Value
	CS 2.5	CS 3.0	CS 3.5		
Fresh Colour					
L					
All (Singles and Multiples)	32.9	33.0	33.0	0.19	0.77
Scanned multiples	32.8	33.0	33.0	0.14	0.36
Birth multiples	32.8	33.0	33.0	0.13	0.39
Birth Singles	32.9	33.0	33.1	0.48	0.95
a					
All (Singles and Multiples)	15.1	15.4	15.3	0.20	0.35
Scanned multiples	15.0	15.3	15.3	0.20	0.27
Birth multiples	15.0	15.3	15.3	0.20	0.27
Birth Singles	15.4	15.4	15.4	0.26	0.96
b					
All (Singles and Multiples)	7.5	7.8	7.7	0.12	0.17
Scanned multiples	7.5	7.8	7.7	0.11	**0.038**
Birth multiples	7.5	7.8	7.7	0.11	**0.042**
Birth Singles	7.8	7.8	7.8	0.18	0.99
Shear Force (Day 5)					
All (Singles and Multiples)	32.3	31.6	30.6	0.93	0.21
Scanned multiples	32.9	31.3	31.1	0.87	0.11
Birth multiples	32.9	31.3	31.3	0.84	0.12
Birth Singles	30.7	31.4	29.2	2.61	0.69

Effects of gestational condition score on retail meat colour values and colour stability in lamb meat

While effects of CS treatment and day of display are observed for several measurements, there was no evidence of a significant interaction between CS treatment and day of display (Table 26). Thus results are presented separately for the effect of CS group (averaged over the 4 display days) and for the effect of display day (averaged over the 3 CS groups, Table 27).

The results in Table 26 indicate there was no significant effect on the retail colour *L* value of lamb meat but there were significant reductions in retail colour *a* values (by 0.6-0.7 units) and *b* values (by 0.5 units) signifying that CS2.5 treatment lamb meat had less redness and yellowness in their retail display colour. There was no significant effects of CS treatment (p=0.14) on the ratio of reflectance of 630nm to 580nm (*R630/580 value*) which is known as the oxymyoglobin to metmyoglobin ratio.

The results of average retail colour data per day of retail display shows a significant effect of the day of display and substantial reduction in the oxymyoglobin to metmyoglobin ratio from day 2 to day 4 with values recorded on average for day 4 being below than the threshold of acceptable colour by consumers (Table 27).

Table 26. Effect of condition score (CS) treatment on average retail meat colour values taken over days 1, 2, 3 and 4.

Retail Colour	CS Group				P Value	
	CS 2.5	CS 3.0	CS 3.5	sed	Main Effect	Interaction with day of display
L value						
All(Singles and Multiples)	30.6	30.5	30.4	0.22	0.72	0.74
Scanned multiples	30.3	30.6	30.3	0.21	0.43	0.50
Birth multiples	30.3	30.6	30.4	0.21	0.45	0.60
a value						
All(Singles and Multiples)	9.1	9.5	9.5	0.17	**0.034**	0.53
Scanned multiples	8.8	9.4	9.4	0.22	**0.023**	0.66
Birth multiples	8.7	9.4	9.4	0.21	**0.012**	0.74
Birth Singles	9.7	9.8	9.8	0.22	0.80	0.39
a value adjusted for hot carcass weight						
All(Singles and Multiples)	9.1	9.4	9.5	0.16-0.18	0.11	
Scanned multiples	8.8	9.4	9.4	0.24-0.30	0.089	
Birth multiples	8.7	9.4	9.4	0.23-0.29	**0.046**	
Birth Singles	9.7	9.8	9.9	0.22	0.70	
b value						
All(Singles and Multiples)	12.2	12.6	12.5	0.13	**0.030**	0.86
Scanned multiples	12.0	12.5	12.5	0.16	**0.0081**	0.94
Birth multiples	12.0	12.5	12.5	0.16	**0.0061**	0.93
Birth Singles	12.5	12.7	12.8	0.12	0.13	0.53
b value adjusted for hot carcass weight						
All(Singles and Multiples)	12.2	12.6	12.5	0.14-0.16	0.067	
Scanned multiples	11.9	12.6	12.5	0.17-0.21	**0.013**	
Birth multiples	11.9	12.6	12.5	0.17-0.22	**0.011**	
Birth Singles	12.5	12.7	12.8	0.12	0.13	
R630/580 value						
All(Singles and Multiples)	3.44	3.54	3.50	0.054	0.17	0.55
Scanned multiples	3.38	3.49	3.47	0.067	0.21	0.33
Birth multiples	3.36	3.49	3.48	0.068	0.14	0.45
R630/580 value adjusted for hot carcass weight						
All(Singles and Multiples)	3.46	3.52	3.51	0.052-0.058	0.56	
Scanned multiples	3.40	3.47	3.47	0.071-0.089	0.64	
Birth multiples	3.38	3.48	3.48	0.0730-0.093	0.47	

Table 27. Effect of day of measurement on retail meat colour values (averaged across condition score treatments).

Retail Colour Stability	Day 1	Day 2	Day 3	Day 4	sed	P Value
L value						
All(Singles and Multiples)	29.5	30.7	30.5	31.3	0.17	**2.6×10^{-10}**
Scanned multiples	29.5	30.6	30.3	31.1	0.17	**3.4×10^{-9}**
Birth multiples	29.5	30.6	30.3	31.2	0.17	**6.6×10^{-7}**
a value						
All(Singles and Multiples)	7.4	10.6	10.2	9.2	0.10	**1.6×10^{-26}**
Scanned multiples	7.1	10.5	10.1	9.1	0.09	**8.8×10^{-23}**
Birth multiples	7.1	10.5	10.1	9.0	0.09	**4.7×10^{-22}**
Birth Singles	7.9	11.1	10.6	9.6	0.14	**2.9×10^{-20}**
b value						
All(Singles and Multiples)	10.4	13.6	13.4	12.4	0.16	**3.4×10^{-22}**
Scanned multiples	10.3	13.5	13.3	12.3	0.16	**7.7×10^{-23}**
Birth multiples	10.3	13.5	13.3	12.3	0.15	**7.8×10^{-22}**
Birth Singles	10.8	14.0	13.3	12.6	0.19	**2.4×10^{-20}**
R630/580 value						
All(Singles and Multiples)	3.62	3.84	3.50	3.02	0.036	**3.3×10^{-20}**
Scanned multiples	3.54	3.79	3.47	3.00	0.032	**4.6×10^{-18}**
Birth multiples	3.54	3.79	3.46	3.00	0.032	**1.2×10^{-17}**

The impact of feedlot rations on prime lamb performance, carcass traits and meat quality

Effects of diet on lamb growth, body composition, fat and eye muscle depth during feedlot finishing

There were very few significant effects of the feedlot diet on any of the measurements taken during the feedlot finishing phase and prior to fasting at end of feedlot period (Table 28). It should be noted that due to the experimental design the feedlot diet treatment had only low degrees of freedom and as such the detection of significant effects may be due in part to insufficient precision in the study.

The feedlot exit weights for both multiples and single lambs tended to be higher for the moderate energy and high protein diet (by 1.1 to 1.5kg, p=0.14 and by 3.3 to 4.3kg, p=0.069 respectively). This appeared to be the result of higher liveweight gain in both multiples and singles on this diet (p=0.22 and p=0.017 respectively).

There were no significant effects of diet on either the DXA measures of body composition of lean, fat or ash at the mid-feedlot measurement or the ultrasound measures of fat and eye muscle depth undertaken near the end of finishing (Table 28).

Table 28. The feedlot entry weight, exit weight, liveweight gain and body composition of lambs on different feedlot diets varying in metabolisable energy (ME) and crude protein content (CP) during the finishing phase. (Values in bold indicate a significant effect)

	Feedlot diet				
	HighE HighP	HighE ModP	ModE HighP	sed	P Value
Weight					
Feedlot entry weight (kg)					
All (Singles and Multiples)	30.4	30.3	30.5	0.44	0.94
Birth multiples					
Birth singles	34.8	34.2	35.7	1.03	0.43
Feedlot exit weight (kg)					
All (Singles and Multiples)	52.6	52.2	54.3	1.02	0.22
Birth multiples	50.7	51.1	52.2	0.59	0.14
Birth singles	56.9	55.9	60.2	1.34	0.069
Feedlot weight gain (kg)					
All (Singles and Multiples)	22.1	22.1	23.7	0.60	0.085
Birth multiples	21.9	22.3	23.3	0.69	0.22
Birth singles	22.2	21.6	24.5	0.59	**0.017**
Feedlot relative weight gain (% per day)					
All (Singles and Multiples)	0.77	0.78	0.81	0.014	0.10
Birth multiples	0.80	0.82	0.84	0.025	0.40
Birth singles	0.69	0.69	0.74	0.021	0.16
DXA mid-feedlot					
Adjusted lean (%)					
All (Singles and Multiples)	77.1	78.1	77.0	0.50	0.26
Birth multiples	77.5	78.5	77.4	0.58	0.34
Birth singles	76.1	77.3	75.9	0.44	0.14
Adjusted fat (%)					
All (Singles and Multiples)	18.9	17.4	18.9	0.61	0.21
Birth multiples	18.5	17.2	18.5	0.76	0.35
Birth singles	19.7	17.9	19.8	0.53	0.11
Adjusted ash (%)					
All (Singles and Multiples)	3.2	3.1	3.3	0.14	0.32
Birth multiples	3.2	3.1	3.4	0.15	0.31
Birth singles	3.0	3.0	3.1	0.11	0.49
Ultrasound (late feedlot)					
Eye muscle depth					
All (Singles and Multiples)	33.5	33.5	33.7	0.66	0.94
Birth multiples	32.9	33.2	33.5	0.62	0.70
Birth singles	35.3	34.5	35.4	1.02	0.63
Fat depth					
All (Singles and Multiples)	4.60	4.70	4.82	0.186	0.53
Birth multiples	4.54	4.60	4.66	0.215	0.86
Birth singles	4.95	5.04	5.35	0.245	0.34

Effects of diet on carcass weight and body composition

There is evidence that lambs finished on the moderate energy, high crude protein diet had a greater final empty body weight (Table 29, $p<0.05$) than the other two feedlot diets. This effect occurred in both in single and multiple lambs. The difference is in the order of 0.9 to 0.3kg for multiple lambs and 3 to 3.9kg in single lambs.

However, this effect was not carried through to the dressing percentage or the carcass weight in either singles or multiples. There were no significant differences for dressing percentage or carcass weight. So despite trends in these values that suggest dressing percentage may have offset and reduced the translation of a difference in liveweight to a difference in carcass weight we cannot tell whether the feedlot diet effect on live weight is reflected in a feedlot diet effect on carcass weight.

Generally, there is little evidence of feedlot diet effects on body composition, whether measured using DXA, abattoir measurements, partial bone out or full bone out (Tables 30 to 32). The reason for this is a combination of precision of slaughter measurements and the similarity between outcomes of the three diets.

There was some statistical evidence of a feedlot diet effect on DXA measured ash content in multiple lambs (Table 30). Although not significant there also appears to be a trend for lower lean percentage and greater fat percentage in multiple lambs (~1.5%, $p=0.12$ and $p=0.14$ respectively) derived from the moderate energy high protein diet.

There were also no significant effects of diet on the intramuscular fat levels of lambs (Table 33).

Table 29. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on pre-slaughter weight, dressing percentage and hot carcass weight of lambs. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

	Feedlot diet				
	HighE HighP	**HighE ModP**	**ModE HighP**	**sed**	**P Value**
Weight					
Final empty body weight (kg)					
All (Singles and Multiples)	51.2	50.9	52.7	0.72	0.13
Scanned multiples	49.5	49.7	50.7	0.19	**0.0073**
Birth multiples	49.4	49.8	50.7	0.26	**0.018**
Scanned singles	54.8	54.6	58.0	0.90	**0.034**
Birth singles	55.4	54.5	58.4	0.88	**0.025**
Dressing Percentage (%)					
All (Singles and Multiples)	49.4	49.5	48.9	0.36	0.29
Scanned multiples	49.3	49.3	48.6	0.45	0.35
Birth multiples	49.2	49.3	48.7	0.45	0.37
Scanned singles	50.1	49.8	49.5	0.63	0.65
Birth singles	50.2	49.8	49.5	0.63	0.60
Hot carcass weight (kg)					
All (Singles and Multiples)	25.3	25.3	25.8	0.39	0.77
Scanned multiples	24.4	24.6	24.7	0.18	0.32
Birth multiples	24.3	24.6	24.7	0.22	0.27
Scanned singles	27.5	27.3	28.7	0.67	0.18
Birth singles	27.8	27.1	28.9	0.63	0.11

Table 30. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on DXA assessed carcass composition of lambs. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Carcass DXA	**Feedlot diet** **HighE HighP**	**HighE ModP**	**ModE HighP**	**sed**	**P Value**
Adjusted lean (%)					
All (Singles and Multiples)	63.0	62.8	61.9	0.56	0.20
Scanned multiples	63.4	63.4	61.9	0.60	0.11
Birth multiples	63.5	63.4	61.9	0.62	0.12
Scanned singles	62.0	61.7	62.0	0.83	0.93
Birth singles	61.7	61.6	61.9	0.78	0.92
Adjusted fat (%)					
All (Singles and Multiples)	35.4	35.6	36.5	0.61	0.25
Scanned multiples	35.1	35.1	36.6	0.71	0.16
Birth multiples	35.1	35.1	36.6	0.70	0.14
Scanned singles	36.1	36.5	36.6	1.37	0.93
Birth singles	36.4	36.6	35.8	0.88	0.62
Adjusted ash (%)					
All (Singles and Multiples)	4.3	4.4	4.6	0.10	0.061
Scanned multiples	4.3	4.4	4.7	0.08	**0.011**
Birth multiples	4.3	4.4	4.7	0.08	**0.017**
Scanned singles	4.1	4.4	4.4	0.09	0.085
Birth singles	4.2	4.4	4.4	0.09	0.10

Table 31. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on lean meat yield measures from full or partial bone out of the carcass. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Carcass Dissection Measures	**Feedlot diet** **HighE HighP**	**HighE ModP**	**ModE HighP**	**sed**	**P Value**
Full bone out					
Meat Yield (%)					
All (Singles and Multiples)	56.2	55.9	56.3	0.23	0.41
Fat (%)					
All (Singles and Multiples)	18.6	18.5	18.3	0.34	0.57
Bone (%)					
All (Singles and Multiples)	25.5	25.8	25.5	0.36	0.64
Partial bone out					
Gardiner predicted meat yield (%)					
All (Singles and Multiples)	60.9	60.5	60.2	0.69	0.59
Scanned multiples	61.1	61.0	60.6	0.60	0.70
Birth multiples	61.1	61.0	60.6	0.57	0.67
Three muscle yield (loin, topside, round, %)					
All (Singles and Multiples)	12.5	12.2	12.5	0.23	0.58
Scanned multiples	12.5	12.4	12.5	0.22	0.82
Birth multiples	12.5	12.4	12.5	0.21	0.81
Two bone yield (leg, H)					
All (Singles and Multiples)	7.9	7.8	7.5	0.34	0.60
Scanned multiples	7.9	7.8	7.5	0.37	0.59
Birth multiples	8.0	7.8	7.5	0.37	0.56

Table 32. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on abattoir measures of muscle and fat. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Abattoir Measures	Feedlot diet HighE HighP	HighE ModP	ModE HighP	sed	P Value
Carcass fat score					
All (Singles and Multiples)	3.3	3.2	3.4	0.29	0.76
Scanned multiples	3.2	3.2	3.3	0.32	0.93
Birth multiples	3.2	3.2	3.3	0.32	0.90
GR 12th					
All (Singles and Multiples)	15.2	15.3	17.3	2.15	0.60
Scanned multiples	15.0	15.1	16.7	2.27	0.73
Birth multiples	15.0	15.1	16.8	2.31	0.71
GR 5th					
All (Singles and Multiples)	6.4	5.5	6.8	0.60	0.21
Scanned multiples	6.5	5.3	6.7	0.49	0.081
Birth multiples	6.5	5.2	6.7	0.48	0.077
C Fat					
All (Singles and Multiples)	5.2	5.4	5.3	0.28	0.80
Scanned multiples	4.9	5.1	5.0	0.13	0.26
Birth multiples	4.9	5.1	5.0	0.16	0.41
EMA (Calculated)					
All (Singles and Multiples)	17.3	17.3	17.3	0.78	1.00
Scanned multiples	17.0	17.2	16.6	0.84	0.80
Birth multiples	16.9	17.3	16.7	0.85	0.81

Table 33. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on intramuscular fat of prime lambs. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

Intramuscular Fat (%)	Feedlot diet HighE HighP	HighE ModP	ModE HighP	sed	P Value
All (Singles and Multiples)	3.37	3.38	3.27	0.237	0.88
Scanned multiples	3.34	3.28	3.37	0.265	0.94
Birth multiples	3.32	3.27	3.34	0.249	0.96
Scanned singles	3.61	3.84	3.06	0.281	0.11
Birth singles	3.56	3.86	3.07	0.295	0.12

Effects of diet on fresh meat colour and shear force

There were no significant effects of the feedlot ration fed during finishing on the fresh meat colour *L* or *a* values or the shear force measurements conducted at day 5 (Table 34).

There was however, a significant effect of the moderate energy high protein diet on the fresh meat colour *a* value particularly for multiples (Table 34). This effect would indicate greater redness (~0.5 units) of the fresh meat colour from these lambs. However it is important to treat this result with caution given the low standard error of difference and the absence of other large dietary effects on colour within the study.

Table 34. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on fresh meat colour and shear force at day 5 of prime lambs. The data is presented for all, single or multiple lambs based on ultrasound scanned data and birth data.

	Feedlot diet				
	HighE HighP	**HighE ModP**	**ModE HighP**	**sed**	**P Value**
Fresh Colour					
L					
All (Singles and Multiples)	33.0	33.0	33.0	0.30	0.99
Scanned Multiples	33.0	33.0	32.9	0.28	0.99
Birth multiples	32.9	33.0	33.0	0.29	0.99
a					
All (Singles and Multiples)	15.0	15.1	15.6	0.17	0.057
Scanned Multiples	15.0	15.0	15.6	0.10	**0.0077**
Birth multiples	15.0	15.0	15.6	0.10	**0.0065**
b					
All (Singles and Multiples)	7.5	7.7	7.9	0.26	0.44
Scanned Multiples	7.5	7.6	7.8	0.20	0.28
Birth multiples	7.5	7.6	7.8	0.20	0.28
Shear Force (Day 5)					
All (Singles and Multiples)	31.3	31.1	32.1	1.35	0.76
Scanned Multiples	32.1	31.2	32.0	1.52	0.82
Birth multiples	32.1	31.1	32.2	1.55	0.75

Effects of feedlot diet on retail colour and retail colour stability
There was no evidence of interaction between diet and day of retail display (Table 35). Therefore results are presented for the effect of diet (averaged over the 4 display days).

The results indicate that there were no significant effects of the feedlot diets fed during finishing on any of the retail colour measures, *L*, *a*, *b* or R630/580 value.

Table 35. Effect of feedlot diet varying in metabolisable energy (ME) and crude protein content (CP) on average retail meat colour values taken over days 1, 2, 3 and 4.

Retail Colour Measurements	High E High P	High E Mod P	Mod E High P	sed	P Value: Main Effect	P Value: Interaction with day of display
L value						
All(Singles and Multiples)	30.6	30.4	30.5	0.19	0.81	0.76
Birth multiples	30.4	30.3	30.5	0.17	0.81	0.74
a value						
All(Singles and Multiples)	9.2	9.3	9.6	0.29	0.50	0.73
Birth multiples	9.1	8.9	9.5	0.26	0.18	0.58
b value						
All(Singles and Multiples)	12.3	12.4	12.6	0.18	0.49	0.93
Birth multiples	12.3	12.2	12.6	0.23	0.32	0.89
R630/580 value						
All(Singles and Multiples)	3.49	3.53	3.47	0.085	0.80	0.25
Birth multiples	3.46	3.43	3.46	0.089	0.92	0.18

The impact of Lean Meat Yield Research Breeding Values on lamb feedlot performance, carcass traits and meat quality

The effects of LMY sire group on feedlot performance
There were in general few significant effects of the LMY sire group on feed lot performance and body composition (Table 36). There was a non-significant trend towards light entry and exit weights for multiple lambs in the high LMY group (p=0.11 and 0.10 respectively) and the low LMY group also appeared to be heavier than the moderate group at feedlot entry (Table 36). The relative liveweight gain of the low LMY group was also greater than the moderate LMY group but not significantly different to the High LMY sires.

There is no evidence of an effect of LMY sire group on DXA measurements at the mid-feedlot scanning (Table 36) but this may be associated with insufficient precision arising from the kill 3 lambs having had no DXA measurements during the feedlot finishing phase.

There is some experimental evidence that progeny from sires in the high LMY RBV grouping have a lower fat depth (0.4 to 0.5mm) than those sires from the low and moderate LMY groups, but there is no evidence that they have greater eye muscle depth (Table 36).

Table 36. The feedlot entry weight, exit weight, liveweight gain and body composition of lambs from different lean meat yield (LMY) sire groups during the finishing phase. (Values in bold indicate a significant effect)

	LMY EBV Grouping			sed	P value		
	Low	**Mod**	**High**		**Overall**	**High vs. others**	**Low vs. mod**
Weight							
Entry weight (kg)							
All (Singles and Multiples)	31.4	29.8	29.9	0.75	0.17	0.35	0.099
Birth multiples	30.3	28.3	27.8	0.85	0.083	0.11	0.075
Birth singles	35.7	34.1	35.0	0.57	0.11	0.84	**0.050**
Exit weight (kg)							
All (Singles and Multiples)	53.5	53.6	52.2	0.89	0.34	0.17	0.92
Birth multiples	52.4	51.5	50.2	0.92	0.18	0.10	0.38
Birth singles	57.6	58.5	56.9	1.65	0.66	0.48	0.60
Feedlot weight gain (kg)							
All (Singles and Multiples)	21.9	23.8	22.2	0.84	0.17	0.44	0.087
Birth multiples	21.9	23.3	22.4	0.66	0.21	0.71	0.10
Birth singles	21.8	24.4	21.9	1.59	0.29	0.43	0.18
Feedlot relative weight gain (% per day)							
All (Singles and Multiples)	0.75	0.84	0.79	0.031	0.11	0.88	**0.048**
Birth multiples	0.77	0.86	0.84	0.031	0.093	0.44	**0.044**
Birth singles	0.65	0.76	0.68	0.041	0.17	0.37	0.093
DXA mid-feedlot							
Adjusted lean (%)							
All (Singles and Multiples)	77.1	77.5	77.4	0.64	0.83	0.83	0.61
Birth multiples	77.4	77.9	78.1	0.70	0.66	0.57	0.52
Birth singles	76.4	76.5	76.2	0.47	0.84	0.63	0.80
Adjusted fat (%)							
All (Singles and Multiples)	18.9	18.3	18.4	0.79	0.75	0.80	0.53
Birth multiples	18.6	17.9	17.8	0.80	0.61	0.54	0.47
Birth singles	19.3	19.0	19.5	0.61	0.75	0.57	0.67
Adjusted ash (%)							
All (Singles and Multiples)	3.1	3.2	3.2	0.14	0.75	0.64	0.60
Birth multiples	3.1	3.3	3.3	0.16	0.60	0.55	0.46
Birth singles	3.0	3.0	3.1	0.10	0.76	0.66	0.61
Ultrasound (late feedlot)							
Eye muscle depth							
All (Singles and Multiples)	33.5	33.5	33.8	0.49	0.78	0.51	0.93
Birth multiples	33.3	33.1	33.2	0.58	0.95	1.00	0.77
Birth singles	35.1	34.5	35.6	0.60	0.32	0.22	0.38
Fat depth							
All (Singles and Multiples)	4.9	4.8	4.4	0.19	0.13	0.063	0.54
Birth multiples	4.8	4.7	4.3	0.17	0.069	**0.032**	0.42
Birth singles	5.3	5.3	4.8	0.28	0.20	0.088	0.91

The effects of LMY sire group on carcass weight and body composition

There were no significant differences in the pre-slaughter weight or carcass weight of LMY sire groups (Table 37). However, there was a non-significant trend for lighter pre-slaughter weight in multiple lambs as LMY RBVs increased with sire grouping (p=0.090) which was similar to the trend observed in feedlot entry and exit live weights shown in Table 36.

Table 37. The pre-slaughter fasted liveweight and hot carcass weight of lambs from different lean meat yield (LMY) sire groups. (Values in bold indicate a significant effect)

	LMY RBV Grouping			sed	P value		
	Low	Mod	High		Overall	High vs. others	Low vs. mod
Weight							
Final empty body weight (kg)							
All (Singles and Multiples)	52.1	52.1	50.7	0.79	0.23	0.10	0.96
Scanned multiples	51.0	50.0	49.0	0.78	0.15	0.093	0.28
Birth multiples	51.0	50.0	48.8	0.86	0.15	0.090	0.32
Scanned singles	56.4	56.5	54.8	1.59	0.55	0.31	0.93
Birth singles	56.2	56.8	55.5	1.71	0.78	0.55	0.78
Hot carcass weight (kg)							
All (Singles and Multiples)	25.6	25.5	25.3	0.48	0.77	0.50	0.91
Scanned multiples	25.0	24.4	24.2	0.57	0.39	0.32	0.35
Birth multiples	25.0	24.4	24.1	0.61	0.38	0.29	0.37
Scanned singles	28.1	27.9	27.7	0.68	0.86	0.64	0.81
Birth singles	28.0	28.0	27.9	0.69	0.99	0.90	0.95

There is experimental evidence (from the carcass DXA measurements in Table 38) that progeny from sires in the high LMY RBV group were chemically leaner (by ~2% units) and had less fat than other sires, but there is no evidence of any further differences between progeny of moderate and low LMY RBV sires.

Table 38. The carcass composition of lambs measured by Dual-X-Ray absorptiometry from different lean meat yield (LMY) sire groups. (Values in bold indicate a significant effect)

Carcass DXA	**LMY RBV Grouping**			**sed**	**P value**		
	Low	**Mod**	**High**		**Overall**	**High vs. others**	**Low vs. mod**
Adjusted lean (%)							
All (Singles and Multiples)	62.0	61.8	64.0	0.86	0.12	**0.050**	0.83
Scanned multiples	62.3	62.1	64.5	0.72	0.051	**0.021**	0.88
Birth multiples	62.3	62.2	64.5	0.74	0.061	**0.025**	0.88
Scanned singles	60.8	61.2	63.4	0.91	0.083	**0.036**	0.64
Birth singles	60.7	61.1	63.2	1.017	0.16	0.074	0.73
Adjusted fat (%)							
All (Singles and Multiples)	36.6	36.8	34.1	1.07	0.12	0.052	0.85
Scanned multiples	36.4	36.6	33.7	0.84	**0.045**	**0.019**	0.79
Birth multiples	36.3	36.6	33.8	0.85	0.055	**0.023**	0.79
Scanned singles	38.4	37.0	34.3	1.27	0.074	**0.037**	0.33
Birth singles	37.6	37.1	34.5	1.45	0.19	0.085	0.77
Adjusted ash (%)							
All (Singles and Multiples)	4.4	4.5	4.4	0.12	0.88	0.91	0.64
Scanned multiples	4.4	4.5	4.5	0.11	0.61	0.98	0.35
Birth multiples	4.4	4.5	4.4	0.12	0.64	0.96	0.37
Scanned singles	4.4	4.2	4.3	0.17	0.76	0.96	0.49
Birth singles	4.4	4.2	4.3	0.18	0.75	0.80	0.50

Results of full half-carcass dissection are shown in Table 39. There is a significant effect in this data for all lambs (singles and multiples) to have higher meat yield in the high LMY sire group, with the difference being similar to the results of DXA scanning. There were no significant effects on full bone out measures of bone and fat percentage.

Table 39. The lean meat yield measurements by full bone out for lambs of different lean meat yield (LMY) sire groups. (Values in bold indicate a significant effect)

Full bone out	**LMY RBV Grouping**			**sed**	**P value**		
	Low	**Mod**	**High**		**Overall**	**High vs. others**	**Low vs. mod**
Meat Yield (%)							
All (Singles and Multiples)	55.6	55.6	57.3	0.64	0.092	**0.039**	0.98
Birth multiples	56.4	55.5	57.4	0.64	0.095	0.054	0.26
Fat (%)							
All (Singles and Multiples)	19.1	19.2	17.1	1.29	0.31	0.15	0.92
Birth multiples	17.9	19.1	16.8	1.25	0.30	0.19	0.40
Bone (%)							
All (Singles and Multiples)	25.6	25.3	25.7	0.74	0.86	0.76	0.66
Birth multiples	26.1	25.6	26.0	0.74	0.75	0.78	0.51

Table 40. shows the results of partial bone out measures for different sire LMY groups. Progeny from high LMY sires were significantly higher (by~2%) in the predicted meat yield based on the equation of Gardiner *et al.* (2010) and this trend was evident in both singles and multiples. However, low and moderate sire groups were not significantly different.

The three muscle bone yield (loin, topside and round) and loin yield of high LMY sired progeny was also greater than the other sire groups with no further differences between low and moderate LMY sires(Table 40). There were no significant effects of LMY sire group on topside or round yield when analysed alone.

The high LMY sire group progeny had significantly lower GR12th and GR 5th fat depth that was also trending similarly in the C fat measurement (Table 41). Carcass fat scores were only higher for low compared to the moderate LMY sire group. There were no significant effects of LMY sire group on any eye muscle measure.

The intra-muscular fat percentage of progeny from high LMY sires was significantly lower (by ~0.6% units) than that of the other sire groups with no further significant differences between the low and moderate LMY groups (Table 42).

Table 40. The lean meat yield measurements by partial bone out for lambs of different lean meat yield (LMY) sire groups. (Values in bold indicate a significant effect)

Partial bone out	**LMY RBV Grouping**			**sed**	**P value**		
	Low	**Mod**	**High**		**Overall**	**High vs. others**	**Low vs. mod**
Gardiner predicted meat yield (%)							
All (Singles and Multiples)	59.9	59.7	62.0	0.67	**0.046**	**0.019**	0.85
Scanned multiples	60.4	60.1	62.4	0.66	**0.045**	**0.019**	0.70
Birth multiples	60.4	60.1	62.4	0.64	**0.042**	**0.017**	0.66
Scanned singles	58.1	59.2	61.4	0.58	**0.012**	**0.0055**	0.15
Birth singles	58.1	59.1	61.3	0.62	**0.015**	**0.0068**	0.20
Three muscle yield (loin, topside, round, %)							
All (Singles and Multiples)	12.2	12.1	12.9	0.29	0.082	**0.035**	0.72
Scanned multiples	12.3	12.1	13.0	0.28	0.074	**0.032**	0.58
Birth multiples	12.3	12.1	13.0	0.27	0.067	**0.029**	0.54
Scanned singles	11.8	12.1	12.8	0.27	**0.041**	**0.018**	0.40
Birth singles	11.8	12.0	12.8	0.28	**0.047**	**0.021**	0.43
Topside yield (%)							
All (Singles and Multiples)	5.1	4.9	5.2	0.16	0.30	0.19	0.40
Scanned multiples	5.1	5.0	5.3	0.15	0.24	0.16	0.34
Birth multiples	5.1	5.0	5.3	0.15	0.24	0.16	0.33
Scanned singles	4.9	5.0	5.2	0.13	0.22	0.11	0.71
Birth singles	4.9	5.0	5.2	0.13	0.24	0.12	0.72
Round yield (%)							
All (Singles and Multiples)	3.8	3.8	3.9	0.08	0.49	0.27	0.83
Scanned multiples	3.9	3.8	3.9	0.07	0.28	0.17	0.43
Birth multiples	3.9	3.8	3.9	0.07	0.28	0.17	0.45
Scanned singles	3.7	3.8	3.9	0.06	0.078	0.081	0.089
Birth singles	3.7	3.8	3.8	0.08	0.20	0.21	0.17
Loin yield (%)							
All (Singles and Multiples)	3.3	3.3	3.8	0.14	**0.043**	**0.018**	0.72
Scanned multiples	3.3	3.4	3.8	0.14	**0.044**	**0.018**	0.73
Birth multiples	3.3	3.4	3.8	0.13	**0.041**	**0.017**	0.76
Scanned singles	3.2	3.3	3.8	0.15	**0.036**	**0.015**	0.69
Birth singles	3.2	3.3	3.8	0.16	**0.041**	**0.017**	0.76
Leg bone yield (%)							
All (Singles and Multiples)	4.2	4.2	4.3	0.09	0.34	0.17	0.93
Scanned multiples	4.2	4.2	4.3	0.09	0.30	0.14	0.89
Birth multiples	4.2	4.2	4.3	0.10	0.47	0.26	0.78
Two bone yield (leg, H)							
All (Singles and Multiples)	7.8	7.6	7.8	0.17	0.48	0.43	0.37
Scanned multiples	7.8	7.6	7.9	0.13	0.20	0.17	0.21
Birth multiples	7.8	7.6	7.9	0.13	0.22	0.18	0.23

Table 41. Abattoir measurements of fat and eye muscle for lambs of different lean meat yield (LMY) sire groups. (Values in bold indicate a significant effect)

	LMY RBV Grouping			sed	P value		
	Low	**Mod**	**High**		**Overall**	**High vs. others**	**Low vs. mod**
Abattoir							
Carcass fat score							
All (Singles and Multiples)	3.4	3.2	3.3	0.03	**0.0027**	0.097	**0.0012**
Scanned multiples	3.4	3.1	3.2	0.07	**0.028**	0.31	**0.013**
Birth multiples	3.4	3.1	3.2	0.07	**0.036**	0.22	**0.018**
GR 12th							
All (Singles and Multiples)	16.4	16.2	15.2	0.49	0.15	0.066	0.72
Scanned multiples	16.1	16.0	14.4	0.33	**0.012**	**0.0046**	0.68
Birth multiples	16.2	15.9	14.5	0.35	**0.018**	**0.0072**	0.58
GR 5th							
All (Singles and Multiples)	6.0	7.2	5.5	0.27	**0.0074**	**0.0083**	0.012
Scanned multiples	5.8	7.2	5.3	0.52	**0.047**	**0.053**	0.056
Birth multiples	5.8	7.2	5.3	0.53	**0.047**	**0.056**	0.053
C Fat							
All (Singles and Multiples)	5.4	5.6	4.8	0.63	0.50	0.28	0.79
Scanned multiples	5.3	5.3	4.5	0.34	0.13	0.055	0.99
Birth multiples	5.2	5.3	4.5	0.35	0.16	0.070	0.95
EMA (L)							
All (Singles and Multiples)	65.7	65.5	66.5	0.79	0.46	0.25	0.79
Scanned multiples	65.7	65.1	65.4	0.63	0.70	0.98	0.43
Birth multiples	65.7	65.2	65.3	0.59	0.74	0.86	0.48
EMA (W)							
All (Singles and Multiples)	32.5	32.4	33.1	0.93	0.78	0.51	0.93
Scanned multiples	32.3	32.1	32.4	0.91	0.92	0.79	0.78
Birth multiples	32.4	32.1	32.4	0.91	0.91	0.82	0.74
EMA (Calculated)							
All (Singles and Multiples)	17.1	17.0	17.7	0.63	0.54	0.30	0.90
Scanned multiples	17.0	16.7	17.1	0.58	0.81	0.65	0.67
Birth multiples	17.0	16.7	17.1	0.58	0.83	0.70	0.66

Table 42. The intramuscular fat of lambs from different lean meat yield (LMY) sire groups. (Values in bold indicate a significant effect)

Intramuscular Fat (%)	LMY RBV Grouping Low	Mod	High	sed	Overall	P value High vs. others	Low vs. mod
IMF							
All (Singles and Multiples)	3.6	3.5	2.9	0.26	0.10	**0.045**	0.64
Scanned multiples	3.6	3.4	2.9	0.26	0.089	**0.040**	0.54
Birth multiples	3.6	3.4	2.9	0.26	0.091	**0.041**	0.52
Scanned singles	3.7	3.8	3.0	0.29	0.098	**0.042**	0.79
Birth singles	3.7	3.8	3.0	0.29	0.096	**0.041**	0.72

The effects of LMY sire group on fresh meat colour and shear force

There is experimental evidence that progeny from sires in the high LMY RBV group have lower fresh meat *a* and *b* values and greater shear force than other sires, but there is no evidence of any further difference between progeny of moderate compared to low LMY sires (Table 43).

Table 43. The fresh meat colour and shear force at day 5 of lambs from different sire lean meat yield (LMY) groups. (Values in bold indicate a significant effect)

	LMY RBV Grouping Low	Mod	High	sed	Overall	P value High vs. others	Low vs. mod
Fresh Colour							
L							
All (Singles and Multiples)	33.5	32.8	32.7	0.28	0.074	0.12	0.058
Scanned multiples	33.5	32.6	32.7	0.33	0.11	0.30	0.062
Birth multiples	33.5	32.6	32.7	0.33	0.11	0.38	0.055
a							
All (Singles and Multiples)	15.4	15.6	14.7	0.22	**0.031**	**0.015**	0.28
Scanned multiples	15.3	15.6	14.7	0.26	**0.053**	**0.024**	0.41
Birth multiples	15.3	15.6	14.7	0.25	**0.051**	**0.023**	0.37
b							
All (Singles and Multiples)	7.8	7.9	7.4	0.07	**0.0048**	**0.0020**	0.17
Scanned multiples	7.7	7.8	7.3	0.09	**0.012**	**0.0049**	0.38
Birth multiples	7.7	7.8	7.3	0.09	**0.0083**	**0.0034**	0.38
Shear Force (Day 5)							
All (Singles and Multiples)	28.3	28.1	38.2	2.44	**0.023**	**0.0090**	0.92
Scanned multiples	28.2	29.0	38.4	3.04	**0.050**	**0.020**	0.81
Birth multiples	28.1	29.0	38.4	3.11	0.052	**0.021**	0.79

The effects of LMY sire group on retail meat colour

The was no evidence of a significant interaction between sire LMY group and day of display (Table 44). Therefore results are presented for the effect of sire LMY group averaged over the 4 days of display. From this data there is no evidence of a sire LMY group effect on retail colour values of *L*, *a* or *b*. The low LMY sire group appear to have lower R630/580 values in comparison to the moderate LMY sire group but this result needs to be treated with caution because it is not congruous with other colour results and LMY sire group effects observed in the study.

Table 44. Effect of Lean Meat Yield Sire Group on average retail meat colour values taken over days 1, 2, 3 and 4. (Values in bold indicate a significant effect)

	LMY RBV Group			sed	P Value					
					Main Effect			Interaction with day of display		
	Low	Mod	High		Overall	High vs. Other	Mod vs. Low	Overall	High vs. Other	Mod vs. Low
L value										
All(Singles and Multiples)	30.9	30.3	30.3	0.42	0.35	0.43	0.23	0.79	0.60	0.70
Birth multiples	30.9	30.2	30.1	0.43	0.28	0.37	0.18	0.70	0.67	0.51
a value										
All(Singles and Multiples)	9.1	9.8	9.1	0.26	0.12	0.27	0.069	0.95	0.77	0.92
Birth multiples	9.0	9.6	8.9	0.23	0.086	0.13	0.072	0.83	0.81	0.60
b value										
All(Singles and Multiples)	12.4	12.7	12.3	0.15	0.12	0.20	0.083	0.95	0.81	0.87
Birth multiples	12.4	12.6	12.1	0.14	0.091	0.055	0.23	0.93	0.75	0.90
R630/580 value										
All(Singles and Multiples)	3.37	3.58	3.53	0.053	**0.038**	0.31	**0.018**	0.36	0.18	0.67
Birth multiples	3.34	3.54	3.46	0.043	**0.021**	0.68	**0.0082**	0.25	0.22	0.28

5. Discussion

This project has comprehensively examined the influence of gestational condition score of the ewe to lambing on lamb and ewe performance, lamb lean meat yield and meat quality for lambs of differing genetic potential for lean meat yield (LMY) and the impact of feedlot nutrition during the finishing phase. The CS treatments were designed to reflect the potential range in commercial systems and the LMY research values represented a range of sires available from the industry. The feedlot finishing system used different diets with varying levels of metabolisable energy and crude protein to assess any possible effects of the finishing phase on shifts in body composition and hence lean meat yield. The nutritive value of the diets offered were high by industry standards but were used to ensure growth of lambs was not limited by the nutrition available during finishing.

An overall key finding from this research with respect to the project objectives, has been the general absence of significant interactions between the main treatments of condition score during gestation, the diet fed during finishing and the Sire LMY group of the progeny. Many of the detected interactions were often in the absence of main effects due to the overarching treatments and were also weak or isolated to particular measures and therefore could be chance effects. The following discussion therefore examines the effects of the main treatments applied in the study in a sequence from the management of the ewe to the finished and then slaughtered lamb.

Maternal ewe condition score and liveweight

The nutritional CS treatments applied during pregnancy successfully resulted in significant divergence of ewe CS and liveweight by lambing. The differences in ewe CS were also supported by a significant change and difference in ewe eye muscle depth and fat depth between CS treatments at day 119, prior to lambing. These differences became smaller at weaning but CS 2.5 treatment ewes were still significantly lighter, lower in CS, with less fat and muscle depth than CS 3.0 and CS 3.5 ewes. The difference in CS and liveweight achieved in these maternal composite first cross Border Leicester Merino ewes, across the CS treatments are within the range achieved in studies with Merino ewes (Ferguson *et al.* 2011 and Oldham *et al.* 2011). However, for a given level of CS difference (0.7) the difference in liveweight (13kg) would appear to be larger than for those studies (van Burgel *et al.* 2011). The degree of CS and liveweight segregation for the ewes in our experiment also appeared to be greater than that of Kenyon *et al.* (2012) where no difference in lamb birth weight was found based on CS differences due to nutrition in late pregnancy in twin bearing ewes. However, the latter study used less sheep and the design relied on individual sheep within a flock rather than the replication of nutritional treatments groups, as used in our study.

Weight changes from marking to weaning in all ewes were characterised by maintenance, slight weight gain or slight weight loss depending on the scanning type (single, multiparous) or CS treatment. In contrast, CS change was more marked with ~0.3 CS recovered in this period for all treatments with the largest change occurring early in this period just following marking. The latter may signify decreasing lactation demands combined with changes in feed quality towards weaning during a dry spring and early pasture hay off but it was not consistent with fat and muscle depth reductions over this period to weaning. The CS response post-marking may therefore have been affected by wool growth during spring (as ewes were only shorn post-weaning) or due to changes in the musculature and fat cover due to recovery of ewes post-lambing.

The responses in twin bearing ewes in terms of fat and muscle depth were greater than singles and signify the greater lactation demands on these ewes. However, based on the similar patterns of CS, liveweight, fat and muscle depth change across all CS treatments there was no indication that ewes in low CS or high CS were more or less responsive to nutrition from marking to weaning. This may not necessarily be the case from lambing to marking, where CS treatments tended to converge more in CS, noting that post-lambing changes in liveweight will reflect both the conceptus and changes due to increased feed on offer.

At weaning ewes from the low CS treatment were still significantly lower in CS (~0.2 CS), liveweight (4-5kg), fat depth and eye muscle depth and twin bearing ewes were further affected. These results confirm the need to manage multiple bearing ewes and ewes in low CS to regain condition following weaning. In contrast single bearing ewes that were managed to achieve high condition score targets (>3.0) at lambing were able reach weaning at a fat and muscle depth approximately equivalent to their allocation levels at CS 3.0. These ewes were also heavier at weaning and had higher CS.

The maternal condition score treatment had significant consequences for wool production and quality with the low CS treatment reducing clean fleece weight, fibre diameter and staple strength. These impacts affect price received particularly for first cross wool and the range in fleece weight response would also influence production and subsequently income per hectare. While prime lamb enterprises are increasingly geared towards low proportions of income from wool sales (Swann 2011, McEachern *et. al.* 2014) the differences between high and low treatments in this study using current prices amount to about $9.41-$11.78/ha ($0.78-$0.98/ewe) at the stocking rates used in the experiment. However, the outcome for first cross ewes with current prices favours the finer diameter and lower fleece weight of the CS 2.5 treatment, whilst the insensitivity of price at the diameter of maternal composite ewes results in the increased fleece weight of the CS 3.5 treatment generating more income. Therefore these changes, although small, should be considered in the economic modelling of optimum condition score profiles for prime lamb production systems. Economic modelling of whole farms systems has shown that increasing fleece weight can increase whole farm profitability of already highly productive prime lamb systems (Jackson *et al. submitted*), although it is not the highest for profitability target for improvements.

Gestational condition score and lamb weight to weaning.

Lambs born to ewes that received declining nutrition during pregnancy were lighter at birth, marking and weaning. These effects between the CS2.5 and CS3.0 treatment are at similar levels of magnitude to that achieved for the range of CS and liveweight profiles examined in Merinos (Oldham *et al.* 2011, Behrendt et al 2011, and Thompson *et al.* 2011). However, while the lower birth weight of lambs from the low CS2.5 treatment was expected the lower birth weight in CS3.5 treatment ewes was not. It may be that higher CS/liveweight gains above CS3.0 may not necessarily result in additional birth weight in lambs born from maternal and cross bred ewes. Other studies have also found inconsistent responses in birth weight to ewe nutrition in late pregnancy (Kenyon *et al.* 2012). Further research is required to determine, if the effect of CS treatment during pregnancy on birth weight is linear or curvilinear.

Gestational condition score, lambs alive and birthweight

The results show that CS 3.5 treatment ewes had more lambs alive at birth and that this effect was carried through to lambs alive at marking and weaning. The effect is approximately 1 extra lamb per 10 ewes but was only present in CS 3.5 treated ewes. No significant impact of the low CS 2.5 treatment was seen on lamb survival for singles or twin scanned ewes. In contrast, there were fewer lambs born alive from single scanned ewes subjected to the CS 3.0 treatment, while CS 2.5 and CS 3.5 were similar. These results are different to those observed in Merinos (Behrendt *et al.* 2011) where high nutrition during pregnancy increased lamb survival to marking quite markedly between an average CS of 2.3 to 3.2 across 15 commercial flocks on farms in southern Australia.

Birth weight has a direct effect on the survival of lambs and the optimum range appears to be between 3.5kg and 6.0kg (Oldham *et al.* 2011, Atkins 1980, and Knight *et al.* 1988). Research in Merinos (Oldham *et al.* 2011) indicated that lamb survival was associated with birth weight responses to changes in maternal live weight during pregnancy. Under this scenario, we would have expected significant effects on birth weight at CS 3.0 in our study to be also reflected in higher lamb survival. However, the results for CS treatment and for twins and singles analysed separately do not suggest a response in survival, if based on birth weight alone. For birth weight, across all lambs CS 3.0 lambs had higher birth weight than CS 2.5 lambs and CS 3.5 lambs were intermediate. But it was the CS3.5 treatment that increased survival but only through twin lambs. This may indicate effects on survival of lambs of condition score separate to those that are mediated through the nutritional influence of CS treatment on birth weight. Dwyer *et al.* (2003) has shown moderate under nutrition impacts maternal behaviour. For example Dwyer *et al.* (2003) showed ewes that on low nutrition spent less time licking their lambs and achieved lower scores for maternal attachment 24 hours after birth. Given the effects in our study largely occurred by the end of birthing it would suggest there may have been effects of CS treatment on changes in mothering, bonding and suckling of the lamb by the ewe, which is critical during the first hours of life.

In contrast, for single bearing ewes and lambs the CS 3.0 treatment had the lowest number of lambs born alive and alive at the end of birthing. Given the alignment with higher birth weight (although not significant in our analysis, $p=0.096$) this may signify greater lamb losses due to lamb size and birthing difficulty. This is somewhat supported by the autopsy data from the study where the CS 3.0 treatment had a higher proportion of lambs in the dystocia category. However, some caution is required with this interpretation as there were too few dead lambs in the data to draw conclusive trends based on the interactions of birth weight, treatment and parity of the dead lambs. The autopsy and survival data presented in this report was on limited numbers of lambs due to the high survival (93.7%) achieved in the experiment under mild and best practice lambing conditions that included the use of tall wheatgrass hedgerows in a maternity ward environment for the twin bearing ewes (see evergraze.com.au). As expected under these conditions, the data suggested that dystocia was the main cause of death in the experiment with starvation, mismothering and exposure (SME) having a lesser role. It is therefore important that further evaluation of CS effects of maternal ewes on lamb survival occurs under commercial lambing conditions and across multiple sites.

An interesting and unexpected aspect of the results was the significant effect on birth weight of CS treatment on male lambs but not female lambs. This is as unusual result since previous studies have found higher birth weights in male lambs and lower survival than females at the same birth weight but the effects of sex were independent of ewe live weight change during pregnancy (Oldham *et al.* 2011). Our results seem to suggest a different level of responsiveness of male lambs in utero to maternal nutrition.

Gestational condition score and lamb growth rate

The responses in marking weight and weaning weight and live weight gain to marking and weaning reflect the trends in birth weight for the CS treatments with lambs born to CS 3.0 treatment ewes having higher weights and weight gain than the CS 2.5 treatment lambs. CS 3.5 treatment lambs were intermediate in live weight and live weight gain. These results show negative effects of lower nutrition during pregnancy on lamb performance to weaning. The difference between CS2.5 and CS3.0 treatments is similar in magnitude to that achieved for the range of CS and liveweight profiles examined in Merinos (Oldham *et al.* 2011, Behrendt *et al.* 2011, and Thompson *et al.* 2011). At birth lambs born to CS 2.5 treated ewes were 230grams lighter than CS 3.0, while at weaning they were 1.8kg lighter. However, analysis of the relative live weight gain from birth to weaning suggests no difference between CS treatments indicating that the changes in liveweight were proportional to the differences observed at birth. Since the CS treatments all received similar levels of nutrition during lactation, this result suggests that small changes to birth weight, set up during pregnancy by CS and nutritional management, will carry through to weaning even when good nutrition is present during lactation. This suggests birth weight provides the footprint for differences in liveweight later in life.

Gestational condition score and lamb fat and muscle at weaning

The CS treatment influences on live weight appear to be reflected in observed trends for eye muscle and fat depth with greater values for lambs born to CS 3.0 ewes than those to CS 2.5 treatment ewes, whilst CS3.5 are intermediate. These differences were correlated with the liveweight of lambs at weaning and appear to be largely driven by differences in liveweight due to CS treatment rather than effects on fat or muscle deposition per se. This interpretation is further supported by the post-weaning results of DXA analysis which shows that lambs born to ewes from declining CS during pregnancy had greater lean and lower fat but when these results were adjusted for the difference in liveweight due to CS treatment they became not significant. The ash content, however, for CS 2.5 lambs was still higher after adjustment for liveweight.

Gestational condition score and body/carcass composition

Low gestational condition score (CS2.5 treatment) resulted in lower feedlot entry weights, exit weights and pre-slaughter weights (p=0.072) for multiple lambs. This effect appears to have carried through to a lower carcass weight that was only significant in multiples. These lighter lambs also had lower eye muscle depth and fat depth when measured by ultrasound prior to slaughter and lower measures of fat (GR12th and Cfat) in the carcass but no significant effects on eye muscle area.

Contrary to previous research (Greenwood *et al.* 1998, Greenwood *et al.* 2010) and our hypothesis that lambs from nutritionally restricted ewes would be fatter, these CS 2.5 treatment lambs also had higher chemical (DXA) lean (%), and a lower chemical (DXA) fat (%) in the live animal measurement mid-way through the finishing phase and in the carcass measurement. This result was conclusive in multiple born lambs but not in singles. Analyses using adjustment for the effect of CS treatment on liveweight show that these fat and lean differences generated during finishing appear to be independent of liveweight. In addition, measures of muscle depth become not significant after adjusting for liveweight, whilst measures of fat depth taken either before slaughter or on the carcass remain close to significant or statistically significant. Taken together, these results suggest the effects of the CS 2.5 treatment on body and carcass composition are primarily through inter-muscular components of fat rather than through differences in muscle mass.

The story from intramuscular fat measurements is less conclusive with no significant effects. However, there does appear to be a trend in IMF values consistent with lower fat (%) as measured by DXA and the statistical probability is improved after adjustment for liveweight (p=0.090 for multiples). Some of the effect on fat percentage may therefore be due to variation IMF.

The fact that our results contrast those of previous studies (Greenwood *et al.* 1998, Greenwood *et al.* 2010) maybe due to the level of maternal under-nutrition tested in this experiment, which was only a 0.4 reduction in lambing condition score for twin bearing ewes and this resulted in a relatively smaller birthweight reduction than those studies cited by Greenwood *et al.* 2010. In our study, the post-natal nutritional environment for both the ewe an lamb was also very good and arguably not limiting to ewe lactation and lamb growth. In addition, our finishing system also delivered high growth rates across the treatments and a high commercially relevant carcass weight. This suggests that under normal commercial farming conditions where ewes are not severely restricted during pregnancy and provided that nutrition during lambing to weaning and finishing are adequate the impacts of ewe CS during pregnancy on body and carcass composition and subsequent lean meat yield are not likely to be large.

Supporting this conclusion is the observation that the greater lean (%) and lower fat (%) observed in DXA (%) was not reflected in any of the measures of lean meat yield both from either the partial bone out and full bone out. There were also very few interactions between CS and other treatments (diet and LMY RBV) for carcass composition measurements. These results taken together with other research in Merinos (Paganoni *et al.* 2013), and given the impact of ewe gestational nutrition on lamb fatness at slaughter was opposite to our hypothesis and only in the order of 1% unit, it can be concluded that low gestational ewe nutrition resulting in lower CS at lambing within an expected commercial range of production will not result in commercially significant effects on the fat content and lean content of prime lambs produced from maternal composite, crossbred or Merino ewes. In addition, the small gain in lean (%) due to the low CS 2.5 treatment, even if it was reflected in lean meat yield, would be more than offset by lower carcass weight at slaughter, resulting in either lower or at best similar amounts of saleable meat when compared to the CS 3.0 treatment. Given the risk of lower lamb and ewe survival due to lower gestational nutrition and CS at lambing including impacts on weaning weight and slaughter weight producers would therefore gain more benefit from managing for these production aspects than for any potential gains in lean meat yield.

Gestational condition score and meat quality/meat colour

Greenwood et al (2010) concluded that there were no effects on the eating quality of sheep meat from nutritional restriction during pregnancy. In our study there was no significant effects on shear force (p=0.12 for birth multiples) or IMF. However, given the trends in the data set these may require further investigation in a larger sample set.

There was however some influence of low CS during pregnancy on the fresh meat colour *b* values and retail colour (*a* and *b* values) of lamb meat. These impacts on meat colour appeared to be a general effect of the CS treatment on meat colour as retail colour stability assessed by the measured oxymyoglobin to metmyoglobin ratio was unaffected. Given the possible trends observed in IMF (although not statistically significant) the changes in fresh meat yellowness could align with the variation in IMF as per phenotypic correlations found by Mortimer *et al.* (2014). However, the phenotypic correlations of IMF with retail colour *a* and *b* values are lower (Mortimer *et al.* 2014) and as such are unlikely to explain the change in retail colour values due

CS treatments. It may be that other factors such as iron content could be different between treatments and this is being investigated.

Impact of finishing diet

While there are generally accepted energy and protein requirements for growing lambs (Standing Committee on Agriculture 1990), the exact energy and protein requirements and the relative importance of energy versus protein content of the diets for fast growing lean lambs of the type finished in this study remains debatable (Jolly 2006). This experiment fed three diets of varying metabolisable energy (ME) and crude protein (CP) in order to determine if there would be additional effects on lamb body composition above those effects of the sire or CS management. The pellet diets used in our study were commercially formulated and manufactured and their tested ME and CP were in general above the typical values for industry standard pellets (Jolly 2006). In particular the protein content was much higher in order to theoretically meet the possibly higher requirements of fast growing high LMY lambs.

There were no significant effects on the various measures of body composition of lambs in this study but there was a significant impact on the pre-slaughter weight of lambs. This did not however translate to carcass weight differences. Due to the necessary limitations of the design structure of the study the finishing component investigating ration effects had the least statistical power and it may be partly due to this limitation that a lack of significant difference was observed. However, the mean performance of all three diets were also generally similar and there were no significant interactions with the LMY sire group and on this basis there is no evidence to suggest differing nutritional requirements between LMY groups.

In general, the feedlot finishing of lambs resulted in good growth rates (>300g/day) across all three rations but the diet with moderate metabolisable energy and high crude protein provided the highest growth rate but at a lower feed conversion ratio (FCR). These results may suggest that the higher crude protein in this ration may compensate for lower ME through increased feed intake enhancing live weight gain but at the cost of reduced feed conversion efficiency. In comparison the more balanced High ME, High CP ration had the lowest feed conversion ratio. However, it is also important to note that due to the commercial formulation of these pellets the ingredients of the diets were not identical. As ME was increased in the diets the percentage of wheat used in the formulation of the pellet was greater, whilst for the moderate energy high protein pellet, some wheat was substituted for almond meal. This means that as expected some of the energy and protein differences are confounded with changes in the composition of the pellet. Keeping this in mind the results suggest there may be some opportunity for stimulating lamb growth rate by either manipulating ME/CP balance and/or the ingredient composition to influence the feed intake. However, caution is required in this approach as the FCR for this diet was worse and despite the higher growth rate and lower cost per tonne of the pellet, the increased intake of pellets resulted in an extra $20/head feeding cost for the finishing of lambs fed the moderate energy and high crude protein diet. This feeding extra feeding cost would be offset partially by the increased pre-slaughter weight. These results show that a diet that combines both high growth and efficiency in terms of FCR will be important for economically finishing prime lambs. There would appear to be more research still required on the relative importance of energy, protein and the efficiency of liveweight gain for finishing lambs that have a high growth potential.

Lean Meat Yield Sire Genetics

Some care should be used in interpreting the results of this study on the impact of LMY RBVs and it's translation to the wider sire population. Our study only used 9 sires (3 per high, moderate and low LMY sire group) and while efforts were made to keep other traits consistent across sires the results achieved may be more related to the sires chosen and their specific ASBVs and RBVs, then to an underlying population trend across all sires. For example, the high LMY sires that were selected for the study also had high shear force and low IMF RBVs and while our results clearly show the impact of those ASBVs, this does not mean that all LMY sires have high shear force or low IMF.

As would be expected selection of high lean meat yield sires using research breeding values result in greater DXA lean and lower DXA fat percentages in the carcass. This was supported by higher lean meat yield values measured under full bone out and with partial dissection utilising the prediction formula of Gardner *et al.* (2010). In particular the effects on the latter of high LMY sires were very significant and this would be expected given the genesis of the RBV for LMY. However, it would appear that the Lean Meat yield as measured by a three muscle yield or the Gardner *et al.* (2010) predicted yield would appear to be mainly influenced by changes in the loin yield, as effects on the yield of topside and round were not significant. The accuracy of the RBV in discriminating low and moderate lean meat yield sires may also require further investigation as differences in low to moderate RBV groups did not translate to significant carcass yield differences. This was also the case for nearly all other traits measured including IMF and shear force where it was the high LMY sires as a group that were significantly different to the low and moderate sires, but there were no significant differences observed between the low and moderate groups in these measures.

The high LMY sires were also leaner for subcutaneous measures of fat on the carcass and by ultrasound pre-slaughter. These sires also had significantly lower IMF and much greater shear force. The size of the shear force difference was substantial at close to 10 units taking the progeny from these sires to values well above the 27N quoted as being acceptable to consumers (Hopkins *et al.* 2006). Likewise the average IMF values at less than 3% would be expected to be less desirable to consumers (Hopkins *et al.* 2006, Warner *et al.* 2010). It should also be noted that in our study with these feedlot finished lambs the average IMF for lambs across sire groups ranged from 3.6% to 2.9% and these are lower than studies undertaken in the Sheep CRC Information Nucleus (Warner *et al.* 2010). This may be due to the impact of ewe background for this experiment and/or the feedlot finishing.

In addition to the above LMY effects the fresh meat colour of high LMY sire group was lower for *a* and *b* values although these differences did not transfer through to retail colour measures. These values for fresh meat colour were still above threshold levels for consumer acceptability (Khiliji *et al.* 2010).

6. Conclusion

The experimental treatments resulted in significant differences in ewe CS and liveweight with concurrent differences in ewe fat and muscle depth prior to lambing. There were also significant changes in fat and muscle depth to weaning. Lamb liveweight at birth, marking, weaning, finishing and at slaughter was reduced by the low CS2.5 treatment on ewes during pregnancy compared to CS 3.0 treatment ewes. Analysis of lambs alive at the end of birthing suggests improved lamb survival for CS 3.5 treated ewes at the rate of 1 extra lamb per 10 ewes. Single born lambs born to CS 3.0 ewes that had the highest average birth weight had lower survival than lambs born to either CS 2.5 or CS 3.5 ewes. Male lambs also appear to have responded to CS treatment with higher birth weight in CS3.0 treatment, while females did not.

This study has also provided clear evidence that the wether progeny of the ewes having declining condition (CS 2.5) during pregnancy have a higher chemical (DXA) lean (%) and a lower chemical (DXA) fat (%) during finishing and in the carcass. This effect is in the opposite direction to that hypothesized at the start of the study based on the literature. The size of these effects (~1% unit) combined with other effects on slaughter and carcass weight mean that the impact of ewe CS management across the range experienced in commercial situations is unlikely to have a commercially significant impact on the amount of saleable meat from a carcass.

There were also few significant interactions with sire LMY genetics or the finishing diet indicating that differences due to sires are likely to hold true under the production systems used in this experiment. Of particular note, the impact of high LMY for sires selected in this study was significant for LMY as measured by DXA, full or partial bone out. However, progeny from this sire group also had significantly lower IMF and much higher shear force than low and moderate LMY sires. This confirms the need to carefully consider IMF and shear force in breeding strategies aiming to improve lean meat yield.

All together the results of this study indicate producers of prime lamb should focus on the lamb survival and increased lamb weight benefits of managing ewe nutrition and condition score during pregnancy and this will at the same time safeguard against possible negative effects of under-nutrition of ewes on the meat quality of the lamb. Further work is required to confirm the response of maternal ewes and their lambs to CS management under a more typical lambing environment experienced in commercial farming conditions.

7. Recommendations

Management guidelines

The recommended management guidelines for maternal ewes to optimise lean meat yield and meat eating quality are presented in detail in Appendix 1 stating the recommended practice with the provision of a brief justification.

The following guidelines for condition score and lamb management have been formulated based on the results of the Nutrition and Lean Meat Yield investigation presented in this report. The recommendations are primarily for twin bearing and triplet bearing ewes as there was insufficient information on the results of single lambs to fully determine the effects of condition score. The guidelines are thus also separated into those directed at the management of all ewes, single or twin-bearing ewes depending on the stage of pregnancy. Further recommendations are also given on the selection of sires to improve LMY, while maintain eating quality.

All ewes

- Manage condition score (CS) at joining to be CS 3.0 or greater.
- Pregnancy scan ewes to determine single and twin bearing ewes and separate into different management groups and tailor nutrition to meet different CS targets at lambing.
- Allocate feed to ewes that are low in condition score so that they can recover some condition during lactation prior to weaning (e.g. ~2,000kg DM/ha and ~11MJ/kg DM metabolisable energy). However, these ewes will still be on average 4-5kg lighter at weaning than if they had been CS 3.0 at lambing so extra post-weaning nutrition will be required to achieve recovery in liveweight and CS to a target of 3.0 by the following joining.

Single bearing ewes

- From pregnancy scanning at approximately CS 3.0 single bearing ewes can be allowed to drop CS to 2.7 at lambing with only small ramifications for future ewe and lamb performance provided the quantity and quality of feed during lactation is adequate.

Twin bearing ewes

- From pregnancy scanning at approximately CS 3.0, increase CS to 3.3 at lambing to increase weaning percentage per twin bearing ewe. A difference of 0.7 CS from a ewe lambing at CS 2.6 versus CS 3.3 could result in an extra lamb for every 10 ewes lambing.
- A CS of 3.0 or greater for multiple bearing ewes at lambing will improve weaning weight, slaughter and carcass weight, whilst possibly improving fresh meat colour and retail colour.
- Twin bearing ewes that are low in CS will not fully recover CS by weaning and therefore need extra post-weaning nutrition to achieve recovery in liveweight and CS to a target of 3.0 by the following joining.

Management of lambs from high lean meat yield sires

- When selecting sires for higher lean meat yield ensure they also have high intramuscular fat and low shear force research breeding values.
- Avoid under-nutrition or low CS during pregnancy of ewes containing progeny from high lean meat yield sires.

Future research

- The impact of CS management on maternal ewe and lamb survival should be researched on a larger population of ewes under commercial lambing conditions to confirm potential benefits of higher CS targets for twin bearing ewes.
- The nature (linear, curvilinear and rate of response) of the response in birth weight to maternal CS during lambing should be determined.
- Modelling of the optimum condition score profile should be conducted and consider impacts on lamb weight.
- It is recommended that further research is conducted into the impacts of CS management of ewes on fresh meat colour and retail colour stability. This should include examination of possible causal mechanisms for the response observed in this experiment.
- It is recommended that further research is conducted into the impacts of CS management of ewes on meat eating quality of their progeny including shear force and IMF. The findings in this study were not significant but need further investigation.
- The long term impacts of CS management on the reproductive rate of ewe lamb progeny should be investigated.
- Investigate methods to improve the retail colour stability and intramuscular fat of feedlot finished lambs.

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9. Appendices

Appendix 1. Management Guidelines

Recommended
Management Guideline

Appendix 2. Draft Media Article

Media Article2 version
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Appendix 3. Draft Paper 1. The effect of gestational nutrition of non-merino ewes on the birthweight, lamb growth and weaning percentage of prime lambs

Draft Paper 1_The
effect of gestational nu

Appendix 4. Draft Paper 2. Declining condition of twin bearing ewes during mid to late pregnancy produces leaner prime lambs

Draft Paper
2_Declining condition o