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Optimising survival, production and immunity of twin-bearing ewes and their lambs

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Abstract

This project was conducted to determine if prepartum supplementation of low fat score (FS; below industry target) twin-bearing Merino ewes could regulate tissue reserves of fat and muscle (i.e. above industry target FS) and ensure survival, production and resistance to major gastrointestinal nematode parasites of ewes and their lambs. Results suggest that high rates of survival of twin-bearing ewes and their lambs can be achieved at lower mid-pregnancy FS provided that ewes have the opportunity to replenish tissue reserves prior to lambing. These results appear to be related to large changes in body composition during the prepartum period. This period is characterised by a metabolic shift towards tissue anabolism in the ewe which optimises the efficiency of use of protein supplements in the Northern Tablelands summer rainfall region. Uncontrolled parasitism with *T. colubriformis* reduced birth weight and *H. contortus* reduced milk yield. The industry implication of this project is that by lowering mid-pregnancy FS targets sheep producers may be able to increase ewe stocking rate. Prepartum management to ensure the ewe has the opportunity to regain tissue reserves of fat and muscle will ensure subsequent survival and production outcomes.

Executive Summary

This project was conducted to determine if prepartum supplementation can substitute for tissue reserves of fat and skeletal muscle to regulate survival and production of twin-bearing Merino ewes and their lambs. Two replicated factorial field experiments were conducted which investigated the treatment effects of mid-pregnancy fat score (FS), prepartum supplementation and worm infection. The commercial relevance of these treatments was to assess the likely impact of managing twin-bearing ewes at FS targets below industry standards as a means of increasing whole-farm stocking rates. The work was conducted in the Northern Tablelands region of NSW which has a summer dominant rainfall pattern and severe winters and pasture, during the prepartum months of winter, is generally of high mass and very low quality.

In both experiments, twin-bearing Merino ewes were deliberately managed to attain a low FS by day 100 of pregnancy and then given the nutritional opportunity to restore tissue reserves by supplementation with cottonseed meal pellets. The compensation displayed by low FS ewes in the last 35-40 days of pregnancy resulted in a very large increase in ewe and lamb survival to mirror that of high FS ewes. The compensation of low FS ewes in response to prepartum supplementation indicated a metabolic shift towards tissue anabolism which is a useful feature for sheep producers to manage. For example, sheep producers have the flexibility to run ewes during pregnancy at FS targets that are below current industry standards, for the Northern Tablelands region, with the caveat that they subsequently provide the ewe with the opportunity to replenish tissue reserves and control infections of gastrointestinal nematode parasites. Uncontrolled infections of *T. colubriformis* reduced birth weight and *H. contortus* reduced milk yield. In contrast to effects on survival, treatments applied during pregnancy had a variable effect on subsequent lamb growth with the duration of the treatment effect into lactation accounting for this variability. These observations indicate that the metabolic predisposition of the periparturient ewe to replenish tissue reserves provides the opportunity to maintain greater ewe stocking rates while safeguarding animal welfare.

The key elements of adopting these actions are the ability and willingness of sheep producers to fat score ewes and to plan appropriate feed resources (eg. supplements, pasture, crop) to allow ewes to gain condition in the last 50 days of pregnancy. The magnitude of effects of lower ewe FS on whole-farm stocking rates will vary among farms depending on factors such as, pasture availability and quality and time of lambing and this precludes an specific estimate of the size of the effect. However, in relation to maintaining FS during pregnancy, it seems reasonable to conclude that these actions alone may allow producers to increase ewe stocking rate by approximately 10% which is an effect additive to those benefits for ewe and lamb survival.

Contents

1 Background

A possible tension exists between increased stocking rates and achieving fat score targets at mating and lambing. Ideal lambing times occur prior to the peak in pasture growth and pregnancy is often maintained during periods of low pasture availability and quality. Maintaining ewe fat score during this period may conflict with optimising stocking rates to maximise per hectare profit.

A key testable question is whether the survival, production and immunity to worms of twin-bearing Merino ewes and their lambs is best optimised by maintaining (or nearly so) ideal ewe fat score targets during pregnancy or by allowing ewes to drop below these targets and then providing a nutritionally-relevant prepartum supplementation. If prepartum supplementation could substitute for tissue reserves (i.e. fat score) then it would be possible to allow ewe fat score to slip between mating and lambing without imposing a large penalty to the ewe while allowing for an increase in stocking rates because of a lower pasture allocation per animal. The industry application of this approach is the consequence for increasing whole-farm stocking rates and hence profit while addressing key welfare issues of reproductive success and immunity to worms.

The background to the experiment described in this report was the effect of prepartum supplementation with cottonseed meal of twin-bearing Merino ewes grazing winter pastures in the northern tablelands on regulating the survival of ewes and their lambs. The initial preliminary experiment was a 2x2x2 factorial design with 2 fat score levels (i.e. FS 2 and 4) reached by day 110 of pregnancy, 2 groups of prepartum supplementation (i.e. 0 or 200 g/hd/day cottonseed (CSM) meal pellets) that spanned the 5-week period prior to lambing and 2 levels of infection (i.e. uninfected or 750 *H. contortus* L3/hd/week) from day 110 of pregnancy. A total of 91 Merino ewes confirmed by ultrasound to be twin-bearing (Merino sires) were grazed on native pastures from day 110 of pregnancy.

Ewe survival was greatest in ewes that reached FS 4 and least in FS 2 and CSM supplementation increased survival but only of FS2 ewes. Lamb survival was also greatest when their dams had reached FS 4 but in this instance CSM supplementation increased lamb survival of both FS groups. A complete description of the data is provided in the Results section of this report. What was unclear from this preliminary experiment were the treatment effects on lamb birth weight (because of predation) and colostrum production and changes in body fat and muscle. It was hypothesised that these effects explained much of the variation in survival and these were investigated in more detail.

2 Project Objectives

The experimental objectives were:

(i) To determine if prepartum supplementation can substitute for tissue reserves of adipose fat and skeletal muscle to regulate survival and production of twin-bearing ewes and their lambs.

(ii) Identify the major potential impact on production per hectare through increases in stocking rate.

3 Methodology

3.1 Experimental design

The order and timing of experimental events is provided in Table 1. On 3 April 2007, intravaginal sponges (fluorogestone acetate; Allstock, Australia) were used to synchronise oestrus in approximately 600 adult Merino ewes. Ewes were separated into 4 equal groups and joined to Merino rams (10% rams) commencing 1 May 2007 for a 10 d period. Ewes were shorn on 18 June 2007. Ultrasound scanning confirmed twin-bearing status on 27 June 2007 and 168 ewes were extracted for experimental purposes and sire group recorded.

The experiment was conducted in the field at the CSIRO Arding research station, Armidale and utilised 168 twin-bearing adult Merino ewes of mixed age. The experiment was a replicated 2 x 2 x 3 factorial design, with 2 levels of FS (low FS group approximately FS 2.5 and the high FS group approximately a FS 4, the FS scale is 1-5 with 5 being the fattest), 2 groups of prepartum supplementation (0 or 200 g/d cottonseed meal) and 3 infection groups (uninfected, infected 1000 L_3/wk *Haemonchus contortus* or infected with 6000 L_3/wk *Trichostrongylus colubriformis*). The design was fully replicated (n = 2 reps per treatment combination) utilising 24 x 1 ha plots comprised of naturalised pastures with an average stocking rate of 6-7 ewes per plot. Representative subsets of ewes were killed 1 week prior to lambing and the remaining ewes at the end of the experiment (i.e. 7 weeks post partum). The experimental design accommodated each of the four experimental periods, namely (i) creation of FS groups; (ii) prepartum supplementation; (iii) parturition; and (iv) lactation. During the period of parturition, approximately half of the remaining ewes (n = 40) were housed in single pens in an animal house and fed *ad-libitum* a roughage (wheaten & lucerne chaff) diet formulated to be similar in quality to the pasture in the field plots. Housing of ewes enabled accurate measurements of colostrum production and birth weights. After lambing was completed (10 days), these ewes returned to join the other ewes in the field. Only the ewes which were rearing twin lambs were maintained after lambing and they were slaughtered at 7 weeks postpartum and their lambs weaned.

3.2 Generating fat score groups

Immediately after pregnancy scanning, ewes were stratified on sire and infection group and randomly allocated to target FS group on the basis of live weight and FS at the time of scanning. Within FS group, ewes were randomly allocated to replicate (n = 2 per FS group) paddock and grazed on naturalised pasture at CSIRO's Arding field station, Armidale from 27 June 2007. Ewes allocated to the FS 4 group (n=86) were grazed in paddocks (area 6-12 ha) with herbage mass exceeding 2,000 kg DM/ha predicted to support maternal weight gain. Ewes allocated to the FS 2 group (n=82) were grazed in paddocks (area 1 ha) with starting herbage mass of 1,000 kg DM/ha which was predicted to facilitate maternal weight loss. Fat score targets were approximated by 10 August 2007.

3.3 Prepartum supplementation

Immediately after FS targets were reached, ewes were stratified on sire, infection and FS group and randomly allocated to prepartum supplementation (0 or 200 g/head/day) on the basis of current live weight and FS. Prepartum supplementation consisted of cottonseed meal pellets (CSM; 45 % crude protein) provided in a shallow trough, three times each week for a 6-week period prior to lambing. Supplement intake by individual sheep was estimated after 4 weeks by incorporating lithium chloride with the pellets and analysing subsequent blood plasma for lithium concentration. The supplementation period commenced on 10 August and was completed on 21 September.

3.4 Infection details

All animals were treated with a combination of effective short-acting drenches at shearing. Animals were stratified on sire group and randomly allocated to infection group on the basis of live weight and FS. Animals were either (i) uninfected; (ii) infected with 1000 L_3/wk *Haemonchus contortus*; or infected with 6000 L_3/wk *Trichostrongylus colubriformis*. Infections were administered orally in 2 equal doses each week, beginning with the generation of FS groups (27 June 2007) and continuing till slaughter. Uninfected animals were serially treated with cydectin LA.

3.5 Animal sampling and measurements

The timing of experimental events is detailed in table 1. Live weight and FS were determined weekly, and faeces were collected from the rectum fortnightly throughout the experiment. Ewes were scanned by ultrasound at the C site located 50 mm from the midline over the 12th rib to determine fat and muscle depth at days -89, -54, -19 and 51. Blood was sampled at key experimental times which were days -92, -71, -56, -29, -14, 0, 7, 14, 28, 41, 51 for later determination of cell count, antibody titre, leptin concentration, protein and albumin. Colostrum yield was determined over the period 1-3h after birth and milk yield over a 4h period on days 14 and 27. Colostrum was subsampled and antibody titre, fat, protein and lactose content determined. Milk was subsampled for later determination of fat, protein and lactose. Approximately half of the animals were euthanised with a captive bolt gun followed by exsanguination on days -12 and the remainder on day 54. At slaughter the following was recovered (i) weight of gravid uterus; (ii) weight of placenta; (iii) weight of foetus; (iv) foetal length and circumference measurements; (v) weight of brown fat depots – only from nil infected ewes; (vi) weight of omental fat; (vii) abomasal, mesenteric and hepatic lymph nodes; (viii) abomasal contents, washings and tissue; (viii) duodenal tissue and small intestinal contents and washings; and (ix) hot carcass weight. The mass of muscle, fat and bone in the carcass was determined from Catscan imaging. Lymph nodes and gut tissue were used to determine local antibody responses and tissue was also used for histological enumeration of effector cells and determination of cytokine profiles using qPCR.

Survival, sex and birth weight were recorded for each lamb at lambing and maternal behaviour was assessed. A maternal behaviour score was given to each ewe based on responses of the ewe to the tagging and handling of their lambs. Lambs were bled at 1h and on days d 1, 7, 14, 28 and 51 relative to the mid point of lambing. Faecal samples for worm egg count were collected from lambs at weaning. A mid-side sample of wool will be collected at the first shearing.

Animal Ethics approval for this work was granted by the University of New England Animal ethics committee. The reference number is as follows UNE # AEC 06/052.

Table 1: List and timing of experimental activities in 2007.

Date	Experimental day relative to mid-point lambing	Activity
3 Apr		Oestrus synchronisation of ewes
1 May	-156	Mating starts
18 Jun	-107	Shearing
27 Jun	-98	Pregnancy scanning
6 Jul	-89	Start of generating FS groups
10 Jul	-85	Larval challenge commenced for infection groups
13 Aug	-51	End of FS generation period and start of prepartum supplement groups
21 Sept	-12	End of prepartum supplement period and prepartum kill
24 Sept	-9	Move ewes to animal house
28 Sept	-5	Start of lambing
3 Oct	0	Mid-point of lambing (50% ewes lambed)
7 Oct	4	End of lambing
15 Oct	12	Ewes transported back to field plots
26 Nov	54	Post partum kill and lambs weaned

3.6 Statistical analysis

Survival of ewes and lambs is reported from the first preliminary experiment and all other data from the experiment described in this report. Ewe and lamb survival data were analysed using nominal and ordinal logistic regression with the computer program JMP (JMP 5.1.2. SAS Institute, Inc. 2004). All other data were analysed using a number of general linear models with the computer program SAS (SAS 1990). The effects included in the models used to analyse the experimental variables for the ewes and lambs were: FS target group; supplement group; infection status; and all two-way interactions. Effects that were not statistically significant (P>0.05) were removed from the model. Analysis of data was conducted in two discrete periods namely the prepartum period and the postpartum period. Repeated measures analysis was used when multiple samples were taken within a period.

Variables that were not normally distributed (ie. Shapiro-Wilks P≤0.05) were subjected to transformation prior to analysis. The effectiveness of the transformations to normalise the data was assessed on the data and on the model residuals by reference to the Shapiro-Wilks statistic. The transformations used are: worm egg count- cube root; worm counts- log base (10)+50 and haematological variables- square root. Back transformed least squares means ± 68% confidence intervals (c.i.) are presented. In all other cases results are expressed as least squares means ± standard error (s.e.).

4 Results

4.1 Ewe and lamb survival at parturition (expt 1)

The FS of the ewe (figure 1a) during mid pregnancy and prepartum CSM supplementation (figure 1b) both had significant effects (p<0.05) on ewe survival at parturition. Ewes from the high FS group and those receiving CSM had significantly higher rates of survival and consequently a lower death rate. The effect of CSM supplementation on ewe survival differed between FS groups such that supplementing low FS ewes increased ewe survival from 68.2% to 95.7% whereas the effect in FS 4 ewes was to increase survival from 95.8% to 100%.

Prepartum supplementation with CSM increased (p<0.05) the number of twin lambs which were both born alive by 21% (figure 2) and the number where both lambs survived to weaning by 19% (p<0.05; figure 3b). There was a suggestion (P=0.15) of an interaction between the effects of FS group and CSM supplementation for lamb survival at birth. Overall, supplementation increased the number of lambs born alive to low FS ewes from 95% to 153% (principally through more twins alive at birth) and to FS 4 ewes from 146% to 160%; from a best possible result of 200%. Lamb survival to weaning was also significantly influenced by the FS group of the ewe. Ewes with a high FS had significantly (p<0.05) more twin lambs alive at weaning. In addition, 22 % more low FS ewes failed to rear a lamb to weaning (figure 3a). Overall, supplementation and FS affected similarly lamb survival to weaning with survival increasing from 85% to 120% for the transition from -/+ CSM supplementation and for low to high FS. There was no indication of an interaction between these effects with lamb survival to weaning being 65% (low FS nil CSM), 100% (low FS + CSM), 105% (high FS nil CSM) and 136% (high FS4 + CSM) which suggests that the effects of FS group and CSM supplementation were additive.

FS group had a significant (p<0.05) effect on the maternal behaviour score (MBS) of the ewe at parturition in experiment 2 (figure 4). Ewes from the low FS group had a greater percentage of ewes rated 1 (ewe flees when a person approaches, shows no interest in the lambs and does not return). In contrast, ewes from the high FS group had a greater percentage of ewes rated 5 (ewe stays close to the shepherd during handling of her lambs), (O'Connor et al. 1985; Lambe et al. 2001). Infection was not statistically significant for lamb survival, ewe survival and maternal behaviour score. In addition, MBS was not subsequently associated with lamb survival.

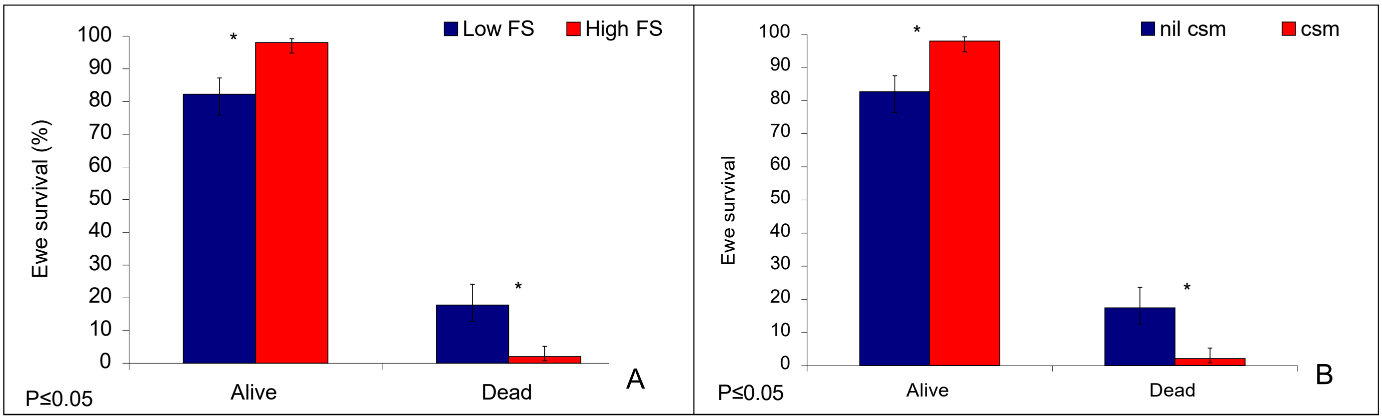


Figure 1: Survival at parturition (lsmeans ± 68% c.i.) of twin-bearing Merino ewes A.) with a low or high FS during mid-pregnancy and B.) receiving either 0 or 200 g/d cottonseed meal prepartum.

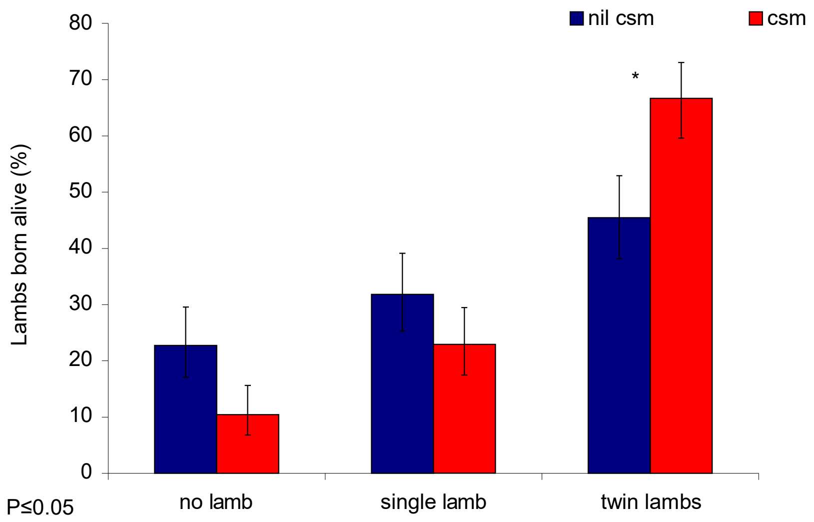


Figure 2: Percentage of twin foetuses where 0, 1 or 2 lambs were born alive (lsmeans ± 68% c.i.) to twin-bearing Merino ewes receiving either 0 or 200 g/d cottonseed meal prepartum.

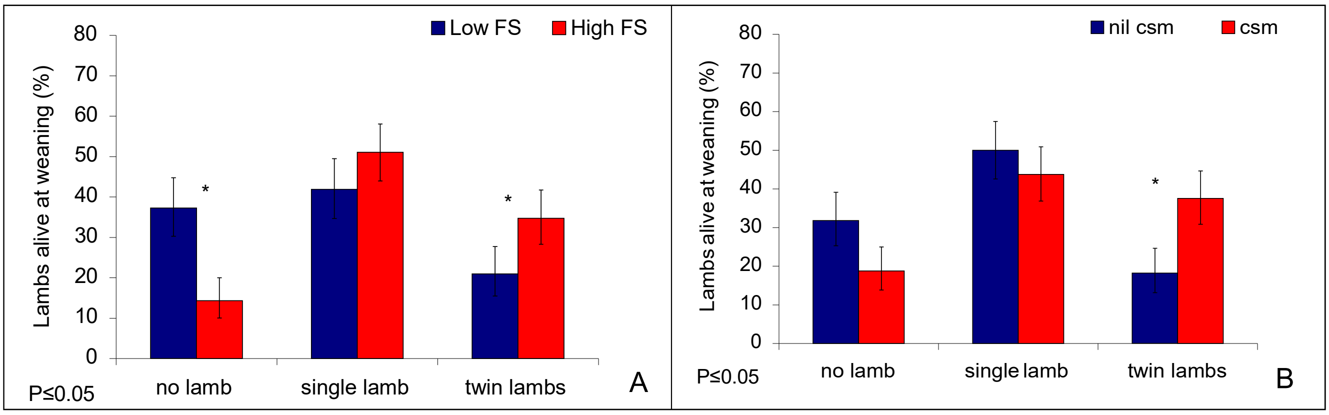


Figure 3: Number of lambs alive at weaning (lsmeans ± 68% c.i.) to twin-bearing Merino ewes A.) with a low or high FS during mid-pregnancy and B.) receiving either 0 or 200 g/d cottonseed meal prepartum.

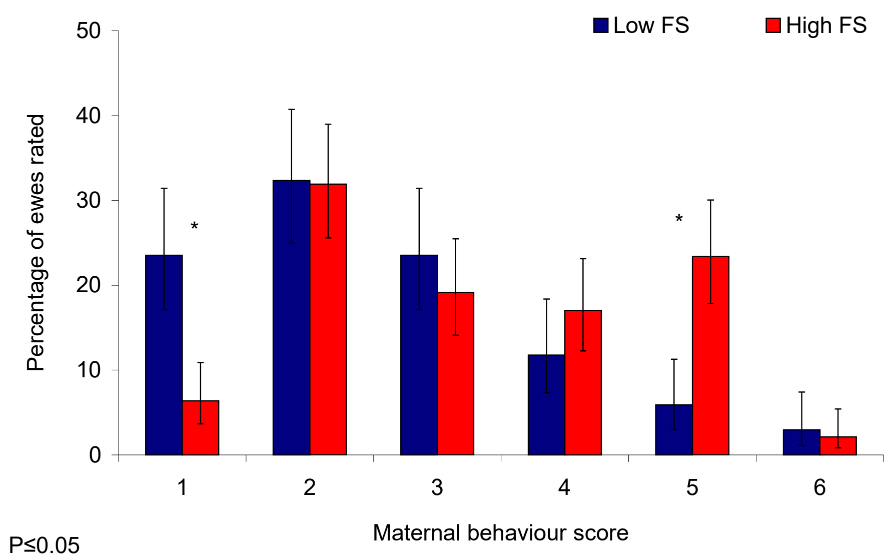


Figure 4: Maternal behaviour score (lsmeans ± 68% c.i.) of twin-bearing Merino ewes with a low or high FS during mid-pregnancy.

4.2 Lamb production traits

4.2.1 Lamb birth weight and body dimensions

Lamb birth weight was determined either *in-utero* (foetal) one week prior to lambing or at lambing. Differences in weight were not significant and foetal and lamb weights were combined. Birth weight was influenced ($p<0.05$) by the infection status of the ewe such that lambs born to nil infected ewes were significantly heavier than those born to ewes infected with *T. colubriformis* but not significantly heavier than those born to ewes infected with *H. contortus* (figure 5a). Regression analysis indicated that birth weight tended to decline with increasing worm count of ewes at the prepartum slaughter. The relationshsips were:

Birth weight (kg) = 3.60 – 0.021 (se = 0.016) abomasal worm count ('000s) (P=0.184)

Birth weight (kg) = 3.60 – 0.034 (se = 0.024) abomasal worm count ('000s) (P=0.147)

Placental weights were unaffected by experimental treatments.

Lambs born to ewes receiving prepartum CSM supplementation were on average 141 ± 0.1 g heavier than those born to unsupplemented ewes (p<0.05). There was a strong suggestion (p=0.06) of an interaction between ewe FS group and prepartum supplementation for lamb birth weight such that, supplementing ewes prepartum increased lamb birth weight in low FS ewes but had no effect on high FS ewes (figure 5b).

Infection, FS, CSM supplementation and the interactions between these effects were not statistically significant for girth circumference and crown to rump length of lambs at birth.

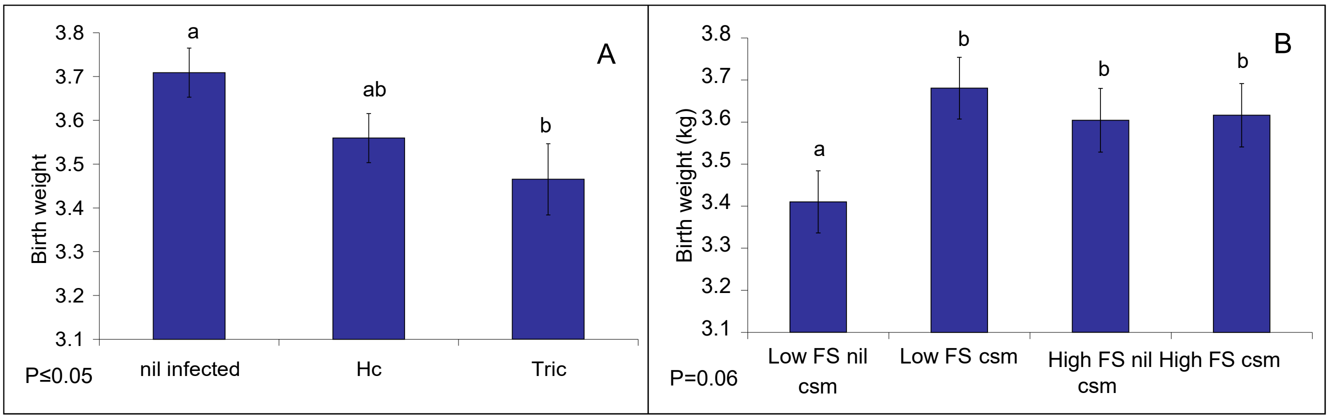


Figure 5: A.) Birth weight (least square means ± s.e.) of Merino lambs born to ewes nil infected or infected with either *H. contortus* (Hc) or *T. colubriformis* (Tric). B.) Birth weight (least square means ± s.e.) of Merino lambs born to ewes with a low or high FS during mid-pregnancy and receiving either 0 (nil) or 200 g/d (csm) cottonseed meal prepartum.

4.2.2 Lamb brown fat reserves

Brown fat reserves of foetuses retrieved from low FS ewes were significantly (p<0.05) greater (figure 6a). There was an interaction (p<0.05) between ewe FS and supplementation for brown fat associated with the heart. The form of the interaction was such that supplementing ewes prepartum decreased brown fat in high FS ewes but had no effect in low FS ewes (figure 6b). Infection, CSM supplementation and the interactions between these effects were not statistically significant for brown fat reserves at birth.

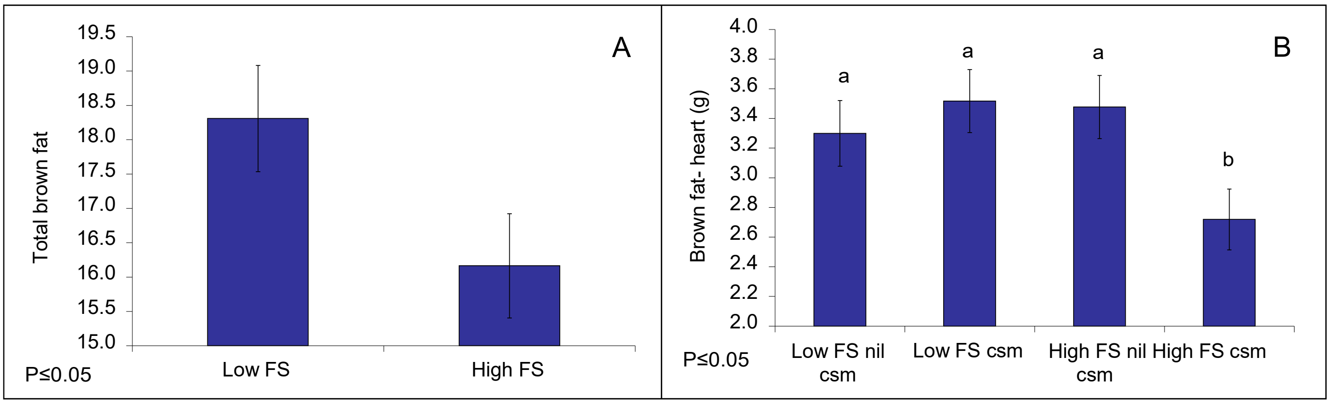


Figure 6: A.) Total brown fat weight at birth (least square means ± s.e.) of Merino lambs born to ewes with a low or high FS during mid-pregnancy. B.) Brown fat weight associated with the heart (least square means ± s.e.) of Merino lambs born to ewes with a low or high FS during mid-pregnancy and receiving either 0 or 200 g/d cottonseed meal prepartum.

4.2.3 Lamb live weight

Lambs born to ewes infected with *H. contortus* continued to be lighter ($p<0.05$) throughout the experimental period compared to uninfected ewes (figure 7). Ewe FS, prepartum supplementation and the interaction between the effects of FS and supplementation were not statistically significant for lamb live weight.

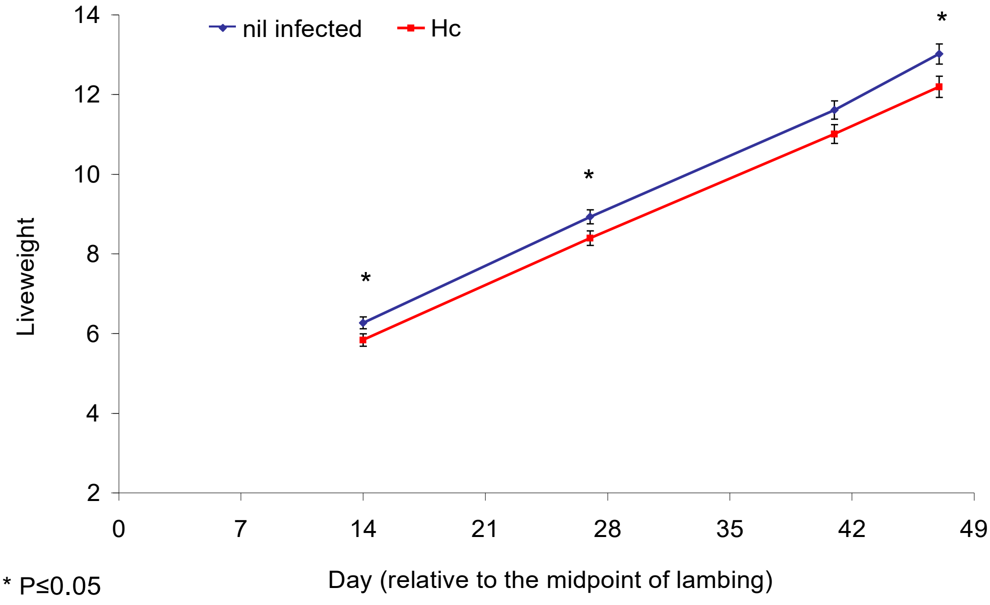


Figure 7: Live weight (least square means ± s.e.) of Merino lambs born to ewes nil infected or infected with either *H. contortus* (Hc).

4.3 Ewe production traits

4.3.1 Lactation

Infection, FS, CSM supplementation and the interactions between these effects had no significant effect on colostrum yield. Infection status of the ewe significantly ($p<0.05$) affected milk production at day 27 but not at day 14 postpartum. Infected ewes produced 281 g/d less milk compared to nil infected ewes (figure 8). Other treatment effects on milk yield were not statistically significant. Colostrum and milk composition has not yet been analysed.

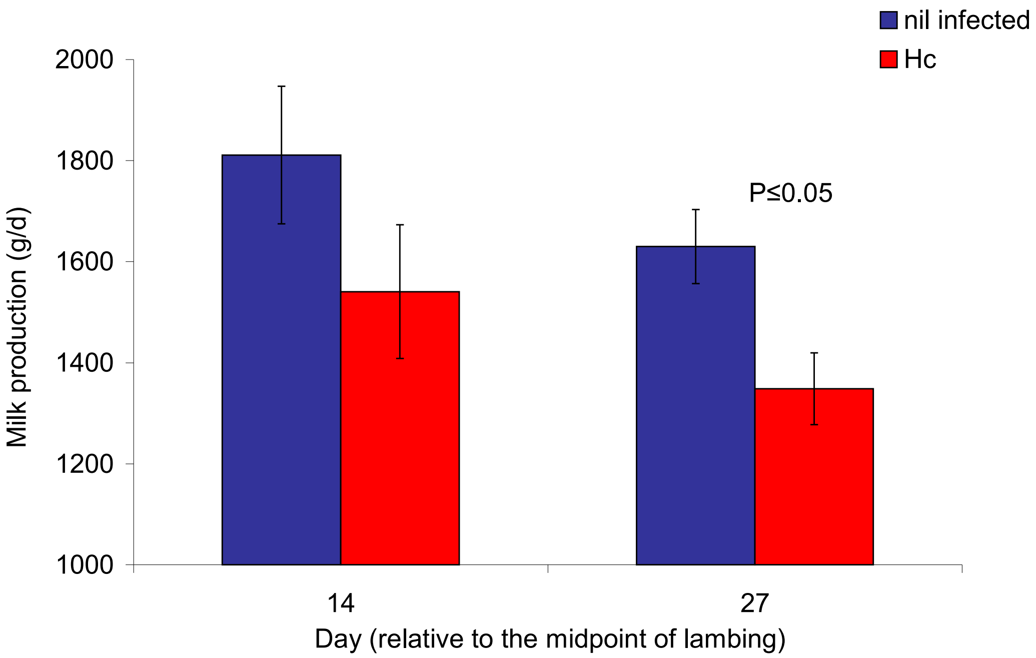


Figure 8: Milk production (least square means ± s.e.) of Merino ewes nil infected or infected with *H. contortus* (Hc).

4.3.2 Ewe live weight and fat score

Initial live weight of ewes allocated to each treatment group did not differ. By day -50 (end of FS period), ewes in the high FS group were 9.1 kg heavier than those from the low FS group and remained significantly ($p<0.05$) heavier throughout the prepartum period. During the postpartum period although both FS groups mobilised tissue reserves, the high FS group did so to a much greater extent such that there was no difference between the treatment groups (figure 9a).

Initial FS of ewes allocated to each treatment group did not differ. Once FS groups had begun to diverge the high FS group had a significantly higher FS throughout the experimental period with the exception of days 0-21 (figure 9b). By day -50 (end of FS period), ewes in the high FS group were 1.3 FS units greater than those from the low FS group. There was no significant effect of infection on ewe live weight during the prepartum period. During the postpartum period, ewes infected with *H. contortus* were lighter ($p<0.05$) when compared to nil infected ewes (figure 10).

Ewes receiving CSM had a significantly greater live weight and FS at the completion of the supplementation period (54.1±0.97, 52.5±1.03 kg and 3.5 ±0.06, 3.2±0.06, respectively). There was an interaction between FS group and prepartum supplementation for FS during the first 3 weeks of the postpartum period. The interaction was such that, supplementing high FS ewes had no significant effect on FS, however, supplementing low FS ewes significantly increased FS at the start of the postpartum period.

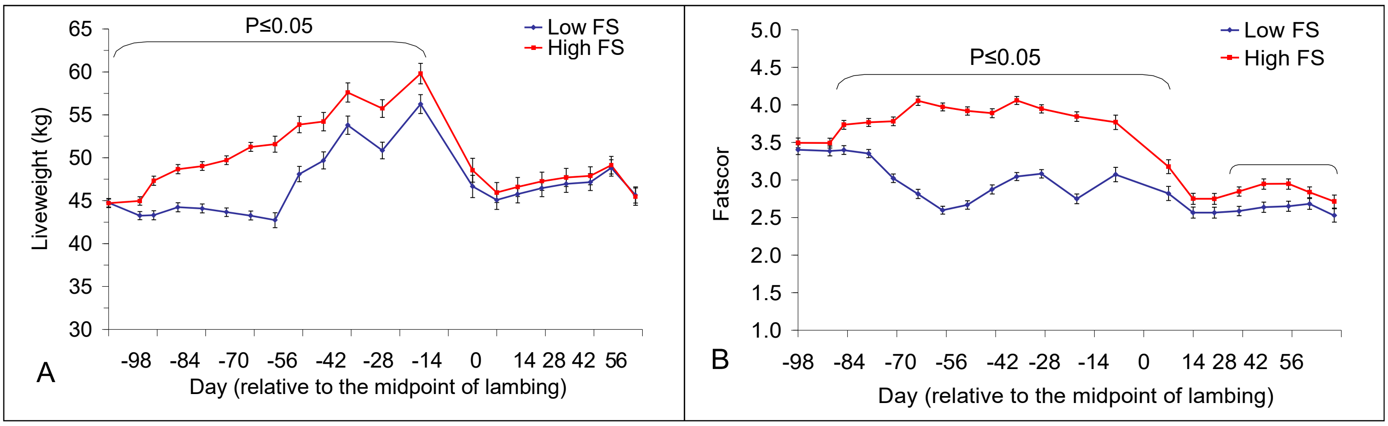


Figure 9: A.) Live weight and B.) Fat score (FS; least square means ± s.e.) of Merino ewes from the low and high FS groups.

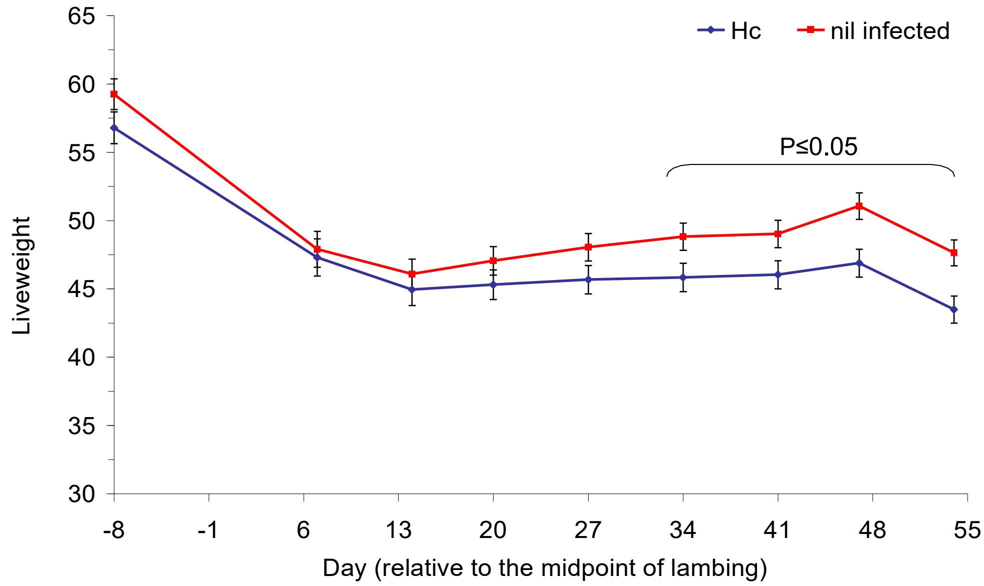


Figure 10: Live weight postpartum (least square means ± s.e.) of Merino ewes nil infected or infected with *H. contortus* (Hc).

4.3.3 Ewe carcass composition

In confirmation of FS differences generated among FS groups, both fat (figure 11a) and eye muscle depth (EMD) (figure 11b) at the C site were greater (p<0.05) in high FS groups at day -60 (near the end of the FS generation period). Greater (p<0.05) tissue depth in high FS ewes continued till day -

19 (near the end of the CSM supplement period) but differences between FS groups had disappeared by the end of the experiment. Neither infection, CSM supplementation or the interactions between these effects were statistically significant for C site fat depth and EMD.

CATscan results for whole carcass composition were consistent with the C site scanning results. Just prior to parturition (day -12) both whole fat and muscle (as component mass and as a proportion of total carcass weight) were significantly greater (p<0.05) in high FS and CSM supplement groups (figures 12 & 13 a/b), but again differences were not evident by the end of the experiment. A positive correlation between C site fat and muscle depth with CATscan fat and muscle mass was observed near parturition (figures 14 a/b). Similarly, FS estimate was positively correlated with CATscan results at the same time (figures 15 a/b).

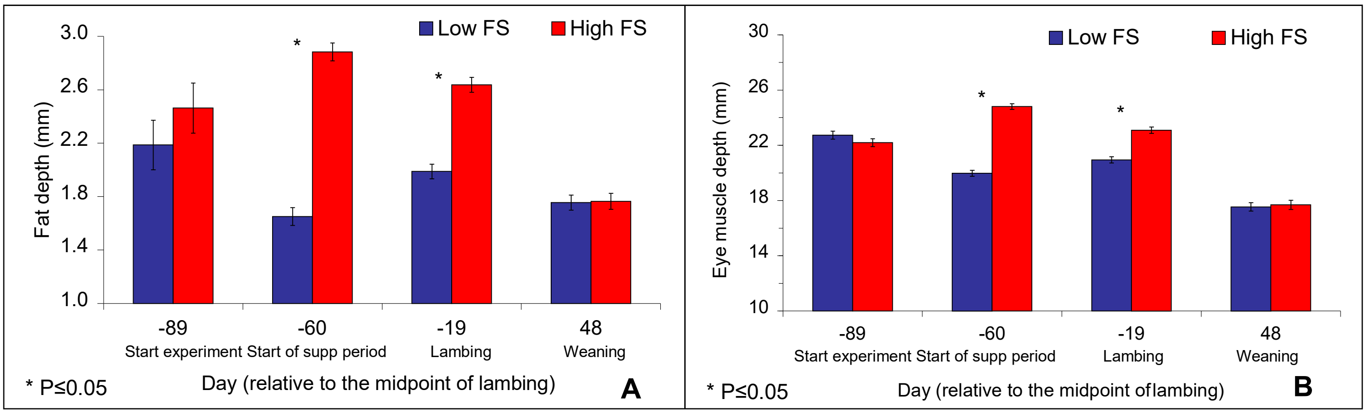


Figure 11: A.) Fat and B.) eye muscle depth (least square means ± s.e.) of Merino ewes with a low or high FS during mid-pregnancy.

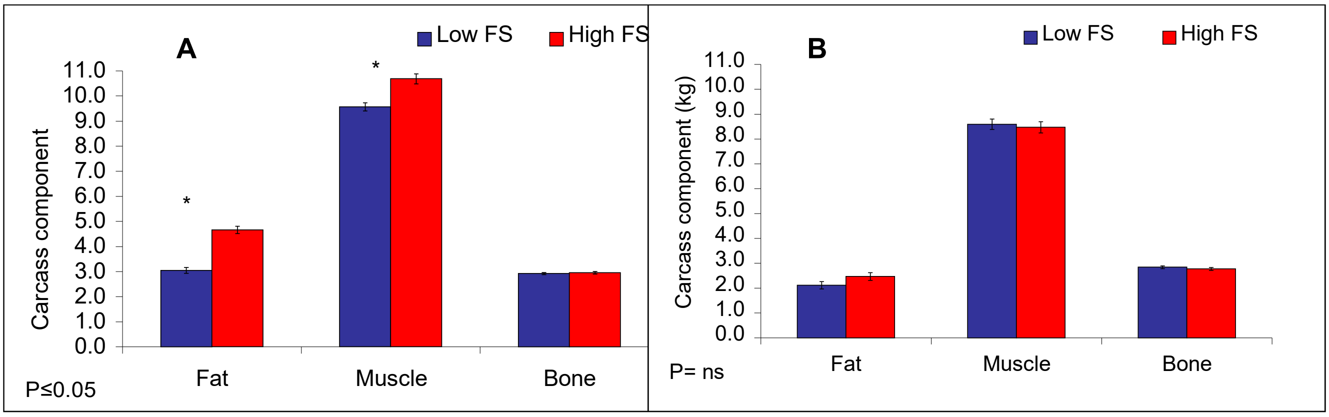


Figure 12: Carcass composition of Merino ewes at A.) parturition (d -12) and B.) weaning (d 54) with low or high FS during mid-pregnancy.

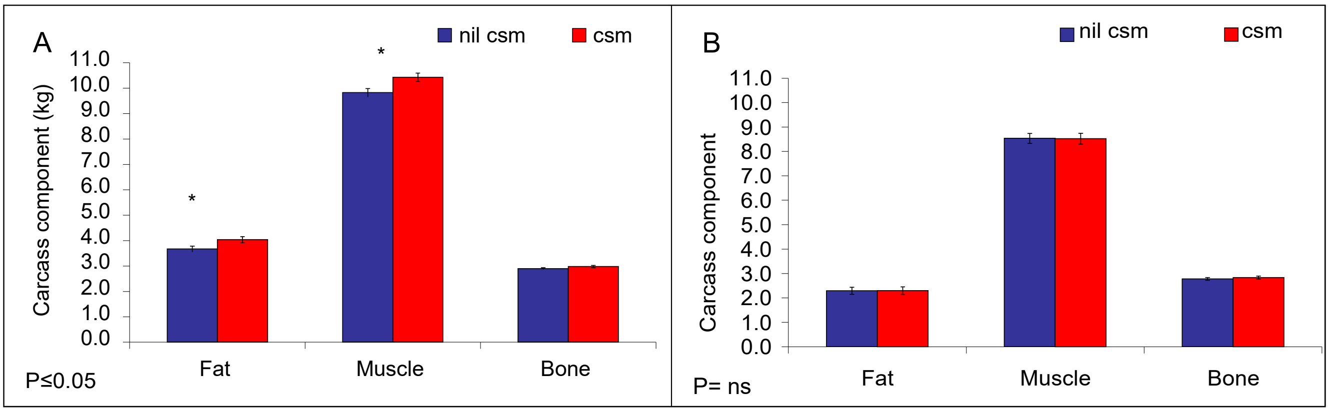


Figure 13: Carcass composition of Merino ewes at A.) parturition (d -12) and B.) weaning (d 54) receiving 0 or 200 g/d of CSM prepartum.

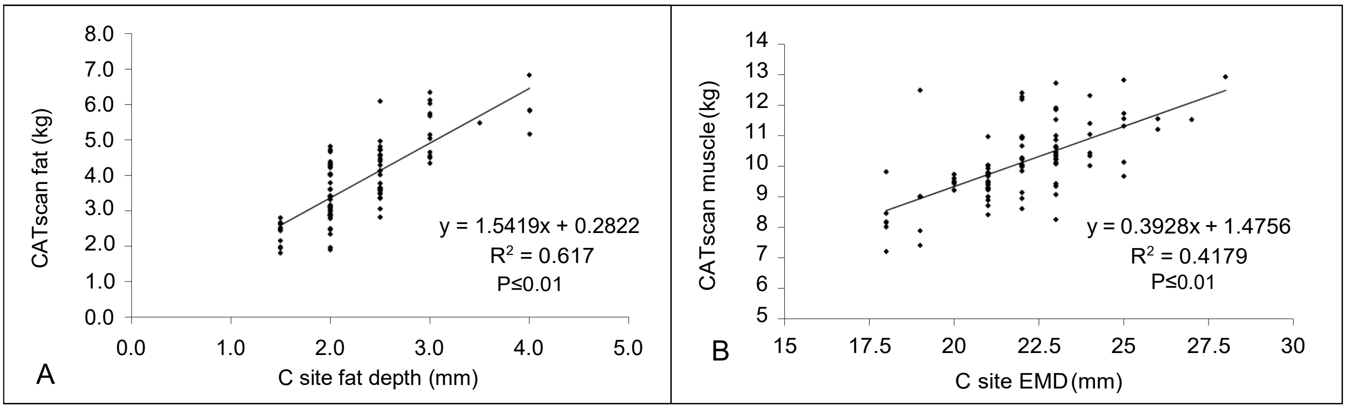


Figure 14: Regression of C site A.) fat depth with CATscan fat mass and B.) eye muscle depth with CATscan muscle mass at day -12.

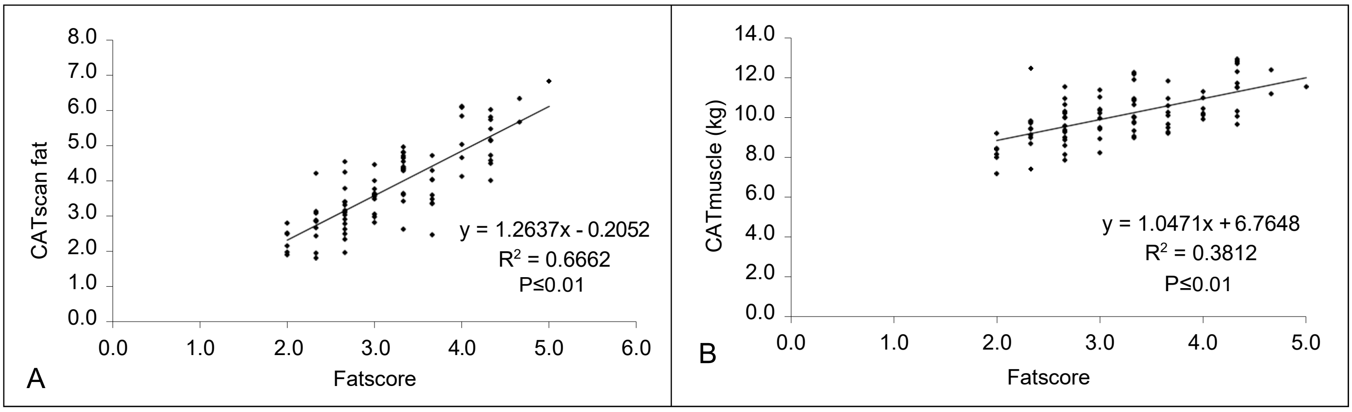
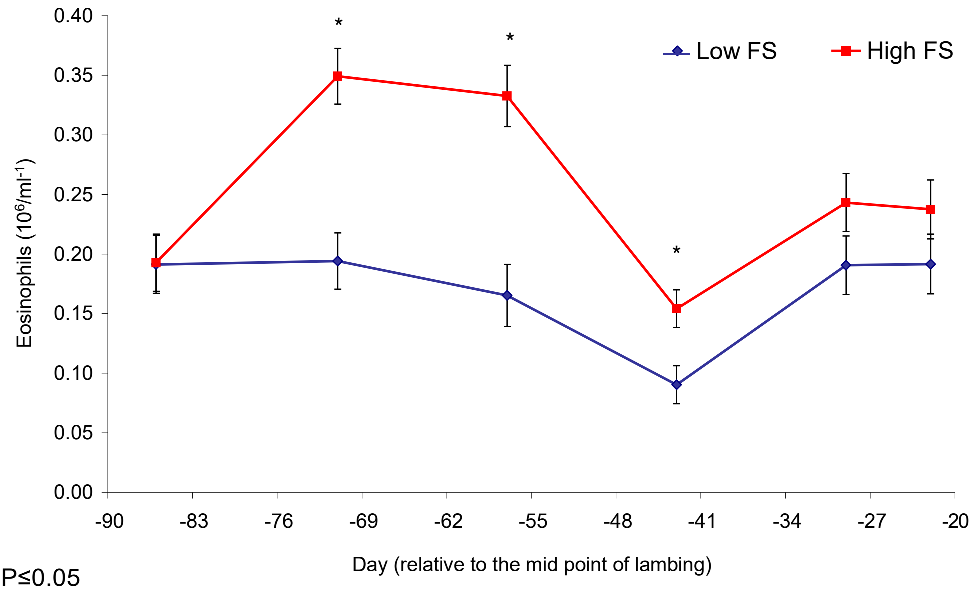


Figure 15: Regression of FS estimate with A.) CATscan fat mass and B.) CATscan muscle mass at day -12.

4.4 Haematology

4.4.1 Eosinophils

There was no difference in eosinophil count between ewes from low or high FS groups at the initial measure (-90 d). During the prepartum period, the profile of ewe eosinophil counts differed over time between FS groups, such that ewes with a high FS during mid pregnancy had a significantly higher count (figure 16). FS group had no significant effect on eosinophil count during parturition or over the postpartum period. Infection and CSM supplementation did not significantly effect ewe eosinophil count over the experimental period.



P≤0.05

Figure 16: Eosinophil count prepartum (lsmeans ± s.e.) of twin bearing Merino ewes with a low or high FS during mid-pregnancy.

4.4.2 Haematocrit and mean corpuscular volume

There was no difference in haematocrit and mean corpuscular volume between ewes from low or high FS groups at the initial measure (-90 d). During the prepartum period, the profile of both ewe haematocrit and mean corpuscular volume differed over time between FS groups, such that ewes with a high FS during mid pregnancy had a significantly higher haematocrit at d -43 to -22 (figure 17a) and a higher mean corpuscular volume at d -71 (figure 17b). FS group had no significant effect on the profile of both ewe hematocrit and mean corpuscular volume during parturition or over the postpartum period. CSM had no significant effect on ewe haematocrit and mean corpuscular volume over the experimental period.

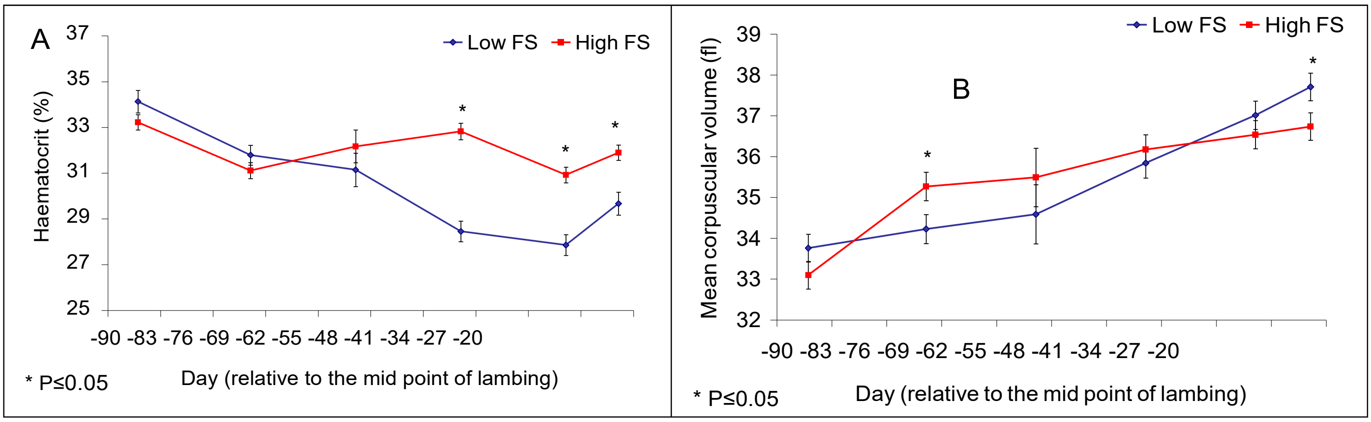


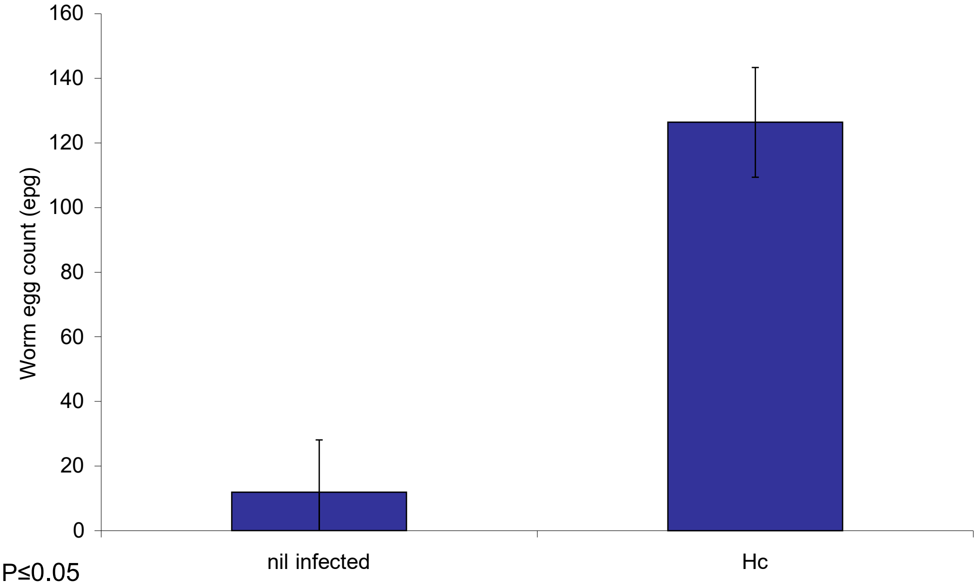
Figure 17: A.) Haematocrit (%) and B.) mean corpuscular volume (fl) (lsmeans ± s.e.) during the prepartum period of twin bearing Merino ewes with a low or high FS during mid-pregnancy.

4.5 Parasitology

Worm egg count was determined on lambs at weaning (54 d). Worm egg count at weaning was low but significantly (P<0.05) higher in lambs born to ewes infected with *H. contortus* compared to those born to nil infected ewes (figure 18), presumably because of infection arising from larval development from eggs shed by infected ewes. Ewe FS, CSM and the interactions between these effects had no significant effect on lamb worm egg count at weaning.

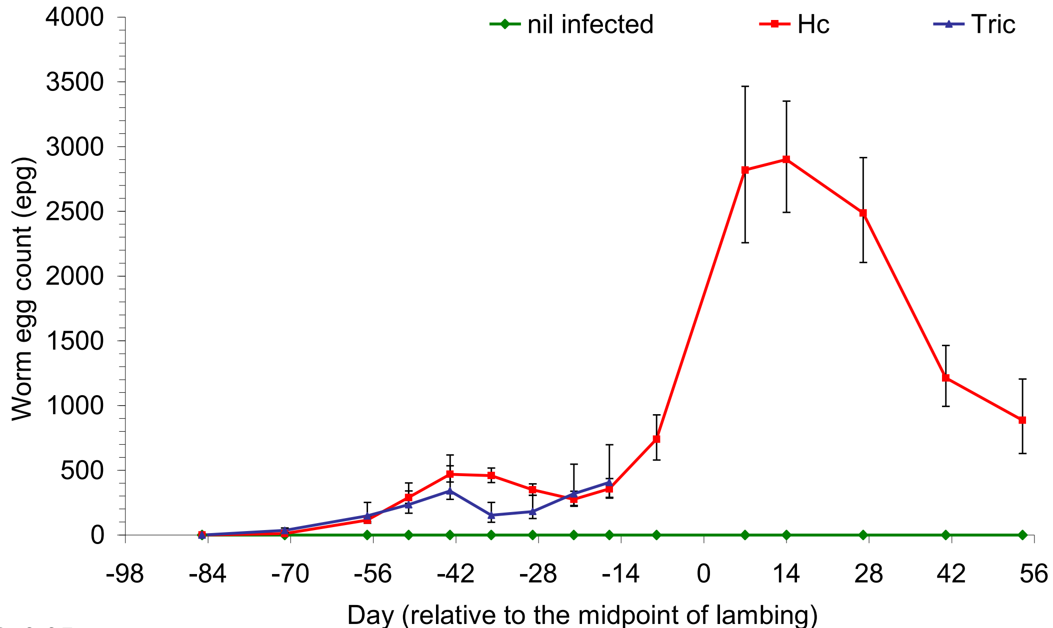
Worm egg counts of nil infected ewes remained negative throughout the experimental period. In contrast, ewes infected with *H. contortus* showed a distinct rise in worm egg count at parturition peaking at 14 d. Ewes infected with *T. colubriformis* showed an increase in worm egg count during the prepartum period prior to slaughter (figure 19). Ewe FS, CSM supplementation and the interactions between these effects had no significant effect on ewe worm egg count during the experimental period.

FS had a significant (P<0.05) effect on abomasal and small intestinal worm counts at day -12 near lambing. FS group influenced worm counts in ewes infected with *H. contortus* such that, low FS ewes had significantly higher numbers of total and immature *H. contortus* (figure 20 a). In addition, these ewes had significantly greater numbers of total *T. colubriformis* worms (figure 20 b) derived from pasture. FS also affected worm counts in ewes infected with *T. colubriformis* such that, low FS ewes had significantly higher numbers of worms including both male and female adult worms in the small intestine (figure 21).



P≤0.05

Figure 18: Back transformed worm egg count (lsmeans±68%c.i.) of Merino lambs grazing with ewes nil infected or infected with *H. contortus.*



P≤0.05

Figure 19: Back transformed worm egg count (lsmeans±68%c.i.) of Merino ewes which are nil infected or infected with *H. contortus* or *T. colubriformis.*

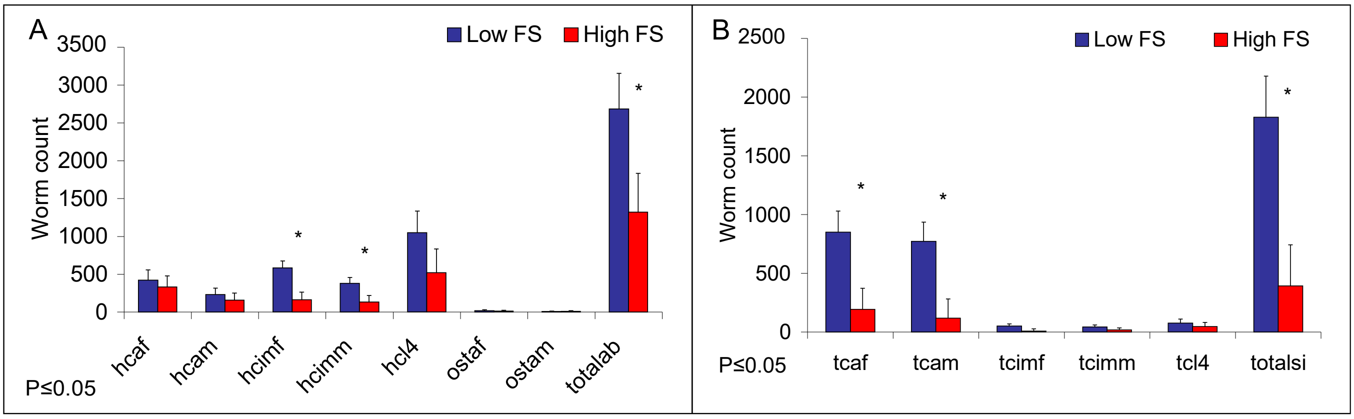


Figure 20: Back transformed (lsmean±68%c.i.) worm counts (day -12) from the A.) abomasum and B.) small intestine of Merino ewes with a high or low FS during mid pregnancy and infected with *H. contortus.* (hc= *H. contortus*, tc=*T. colubriformis*, a= adult, im= immature, l4= 4th stage larvae, f= female and m= male).

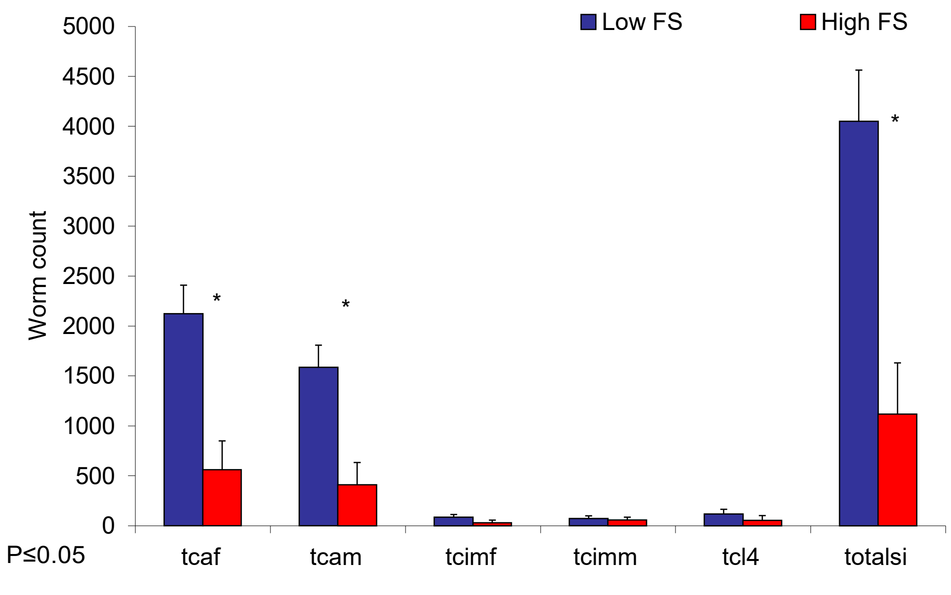


Figure 21: Back transformed small intestine worm counts (lsmean±68%c.i.) at lambing of Merino ewes with a high or low FS during mid pregnancy and infected with *T. colubriformis*.

5 Success in Achieving Objectives

The main objective of this project was to determine if prepartum supplementation can substitute for tissue reserves of adipose fat and skeletal muscle to regulate survival and production of twin-bearing ewes and their lambs. Ewe survival is a key performance trait and both FS and prepartum supplementation with CSM were effective at increasing ewe survival at parturition but the effects were not additive. For example in experiment 1, supplementation increased survival of low FS ewes by 28% points but of high FS ewes by only 4%, because ewe survival of the high FS nil supplement group at 96% was already close to the 100% biological maximum. Lamb survival at birth was also increased by greater FS and prepartum supplementation of the dam and, as for ewe survival, survival of lambs born to low FS ewes was most improved by supplementation. This interaction resulted in lamb survival of low FS supplemented ewes being the same as for high FS unsupplemented. These results suggest strongly that prepartum supplementation was as effective as tissue reserves of fat and muscle, acquired during mid-pregnancy, in minimising the death of twin-bearing ewes and their lambs at lambing.

Ewe survival is regulated by tissue reserves, and lamb survival at birth by birth weight and the availability of colostrum, which in turn are linked to maternal tissue reserves available for catabolism and the current nutrient supply. In experiment 1, low FS ewes were approx. 2 FS units lighter than high FS ewes by day -50 (approx. 1.3 FS units in experiment 2), but subsequent prepartum supplementation reduced this difference to 0.5 FS unit (approx 0.4 FS unit in experiment 2). The extra live weight gain over the supplement period of low FS ewes in response to prepartum supplementation (figure 22) indicates a metabolic shift towards tissue anabolism. This apparent shift was also observed in unsupplemented ewes which displayed signs of compensation during the prepartum period. The extra ewe growth was achieved in response to 7.0 and 8.4 kg of CSM in experiments 1 and 2.

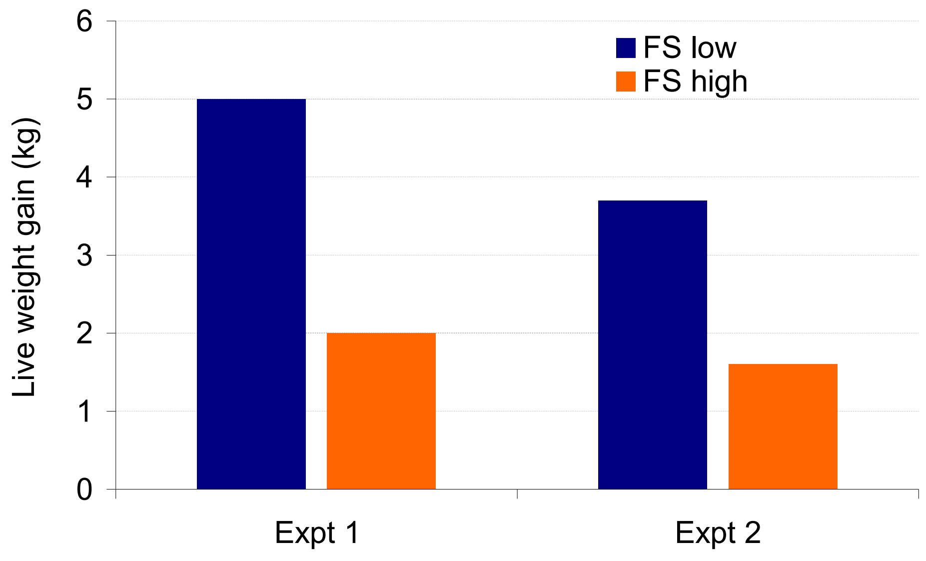


Figure 22 : Live weight gain of twin-bearing Merino ewes due to supplementation with cottonseed meal for 35 days (experiment 1) and 42 days (experiment 2) prior to parturition.

Creation of low and high FS groups during mid-pregnancy did not affect placental weights and, as was observed with maternal live weight, birth weight of lambs born to low FS ewes was increased by supplementation. Surprisingly, treatment effects did not influence colostrum yield and lambs born to low FS ewes had a greater mass of brown fat. It seems probable that the survival benefits of prepartum supplementation to low FS ewes and their lambs is mediated through increased tissue reserves rather than through transfer of early nutrients via the dam.

Neither mid-pregnancy FS or supplementation group influenced significantly milk yield or lamb weight till weaning presumably because of the compensation that occurred prior to lambing and the design of experiment 2 which only retained twin-rearing ewes during the post parturient period. Nevertheless the trend in milk yield at 2 weeks post partum mirrored that of lamb birth weight with supplementation increasing milk yield by 465 g/d and no effect in low and high FS groups respectively. Differences in FS associated with treatments had largely disappeared by day 21 post partum and this would likely account for similar milk yields at 4 weeks post partum and weaning weights at day 54. In contrast, FS differences in experiment 1 persisted for longer into lactation and resulted in greater weaning weights of lambs born to high FS ewes (10.0 vs 12.3 kg).

Scanning the carcasses of ewes after slaughter for compositional data allowed confirmation that FS differences were reflective of changes in fat and muscle depots and will also allow calculation of the energetics associated with treatment effects (as part of doctoral work of F. Macarthur).

Uncontrolled infection with *H. contortus* led to a 15-20% decline in milk yield and lower lamb weights till weaning. Treatment effects on animal health indicated a greater beneficial role of FS group rather than supplementation on systemic indicators of immunity to worms such as eosinophil count, on worm burden and on blood loss (as indicated by greater haematocrit). The effect of FS group on animal performance was greater than for supplementation (though the magnitude of the difference was part of the treatment effect) and apparent over a longer period of time and this may have accounted for its prevailing role in improving animal health.

The second objective of this project was to identify the major potential impact of these results on production per hectare through possible increases in stocking rate. Assessment of the data against this objective indicate that there are (at least) two independent traits that require discussion. The first trait is survival of ewes and lambs and the second is the subsequent growth and animal health to weaning. In both experiments, twin-bearing Merino ewes were deliberately managed to attain a low FS by day 100 of pregnancy and then given the nutritional opportunity to restore tissue reserves. The compensation displayed by low FS ewes in the last 35-40 days of pregnancy resulted in a very large increase in ewe and lamb survival. This indicates that sheep producers may have a degree of flexibility to run ewes during pregnancy at FS targets that are below current industry standards with the caveat that they subsequently provide the ewe with the opportunity to replenish tissue reserves. The ability to increase survival is however quite independent of performance to weaning and the extent to which the management effects of pregnancy FS and prepartum supplementation affect lamb growth will be determined by the duration of their impact.

These experimental observations allow comment on the issue of managing ewe FS in order to optimise production per hectare. The contrast of a low and higher ewe stocking rate will be considered. As stocking rate increases, ewe FS will generally decline but survival of ewes and lambs can be managed to be broadly equivalent to a lower stocking rate by provision of a prepartum nutritional catch-up. However, individual weaning weights are likely to be reduced by increases in stocking rate. Nevertheless, wool cut and the weight of lamb weaned per hectare are likely to be greater with higher stocking rates and the compensatory ability of the Merino ewe is a key aspect of this outcome.

6 Impact on Meat and Livestock Industry – now & in five years time

The results presented in this report have significant implications for the welfare and profitability of twin-bearing Merino ewes and their lambs. There are two primary areas of concern, which are (i) management of the fat score of the ewe and (ii) management of worm infections during pregnancy.

Current industry recommendation for management of ewe fat score, post day 80 of pregnancy, in the Northern Tablelands of NSW is to maintain a FS of 3.0 (http://www.lifetimewool.com.au/Sheep%20Zones/zonenorthtable.aspx). Our results suggest that high rates of survival of twin-bearing Merino ewes and their lambs can be achieved at lower mid-pregnancy FS, provided that ewes have the opportunity to replenish tissue reserves prior to lambing. This message adds value to existing industry action, in that it is more conducive to running greater stocking rates, and it establishes the efficiency of protein supplementation as a means of supporting late pregnancy tissue anabolism in the Northern Tablelands summer rainfall region. The on-farm actions required by managers of twin-bearing Merino ewes are described in Table 2.

Table 2: Managing fat scores of twin-bearing Merino ewes in the last 7 weeks of pregnancy

Fat score at day 100 of pregnancy	Target FS at start of lambing	Need to gain condition from day 100 pregnancy
2 – *below industry acceptance*	3 plus	Yes
2 plus		Yes
3 minus		Yes
3		Yes
3 plus		No
4 minus		No
4		No

Note: Our experimental observations do not include data to confirmed if ewes that present at FS greater than 3 plus at day 100 of pregnancy are better to maintain that condition or still be managed to achieve the target fat score.

The key elements of adopting these actions are the ability of sheep producers to fat score ewes and to plan appropriate feed resources (eg. supplements, pasture, crop) to allow ewes to gain condition in the last 50 days of pregnancy. The magnitude of effects of lower ewe FS on whole-farm stocking rates will vary among farms depending on factors such as, pasture availability and quality and time of lambing and this precludes an accurate estimate of the size of the effect. However, in relation to maintaining FS during pregnancy, it seems reasonable to conclude the following:

1. Reduction of 0.3 FS unit over 100 days will correspond to an approximate weight loss of 20 g/day (assuming 7 kg maternal weight per FS unit).

2. Weight loss of 20 g/day arises from lower pasture intake of 0.5 MJ ME/day (assuming 25 MJ ME / kg weight change).
3. Lower pasture intake translates to a 7% reduction from weight maintenance (assuming maintenance of maternal weight (till day 100 pregnancy) requires 7.5 MJ ME/day).
4. A 7% reduction in pasture intake may support a 7% increase in ewe stocking rate but the actual magnitude may vary (in either direction) according to the factors described earlier and producers' perception and management of risk.

That worm infections reduced birth weight (*T. colubriformis*) and milk yield (*H. contortus*) indicates the importance of managing worm infections in the susceptible periparturient ewe. This lends further support to establishing the cost of worms and adherence to industry control programs such as IPMs.

7 Conclusions and Recommendations

Full recommendations will be provided after the completion of a PhD thesis by F. Macarthur which will better elucidate treatment effects on the immune response. However, the results from this project are sufficiently convincing to warrant work to validate these findings at a larger commercial scale prior to widespread industry extension.

Recommendations and Conclusion from PhD thesis

Recommendations
The research findings indicate that FS of individual ewes should be determined after mating and ultrasound scanning performed to identify twin-bearing ewes. Identification of twin-bearing ewes is important as their nutritional requirement is greater and they will thus be dependent on preferential nutrition. Twin-bearing ewes can then be managed between d -100 to -50 to reach a minimum FS of 2.3. This practice would utilise the natural weight loss of animals in response to low feed quality over winter. From d -50 to lambing, ewes need to increase weight (and consequently fat and protein reserves) through the provision of appropriate nutrition to achieve a target FS at lambing of at least 3.0. CSM was a cost effective supplement providing high levels of bypass protein.

Fat scoring is simple and inexpensive, enables an accurate determination of the current nutritional status of a flock (indicative of previous nutrient availability) and facilitates targeted management at critical stages of a ewe's reproductive cycle. Fat scoring allows producers to overcome inconsistencies in determining a ewe's condition based on LW due to large variations in frame size within a flock and gut fill.

The key elements involved in adopting these experimental findings are the ability of sheep producers to FS ewes, identify dry and twin-bearing ewes, determine pasture availability, and to plan appropriate feed resources (eg. supplements, pasture or crop). The magnitude of the benefits of lower ewe FS on whole-farm stocking rates will vary between farms depending on factors such as pasture availability, pasture quality, and time of lambing. However, in relation to manipulating FS during pregnancy, it seems reasonable to conclude the following:

1. Reduction of 0.6 FS units over 100 days will correspond to an approximate weight loss of 40 g/d (assuming 7 kg maternal weight per FS unit).
2. Weight loss of 40 g/d arises from lower pasture intake of 1.0 MJ ME/d (assuming 25 MJ ME/kg LW change).
3. Lower pasture intake translates to a 13% reduction from weight maintenance (assuming maintenance of maternal weight (till day 100 pregnancy) requires 7.5 MJ ME/d).
4. A 13% reduction in pasture intake may support a 13% increase in ewe stocking rate but the actual magnitude may vary (in either direction) according to the factors described earlier and producers' perception and management of risk.

Increasing the profitability of sheep production in Australia will be a key driver of the industry's long-term sustainability. However, with increased stocking rates there is likely to be an increased threat of exposure to worm infestations through an increase in larval pasture contamination. This drawback highlights the need for a holistic approach to both sheep management and the control of worm infestations.

Manipulating ewe fat and protein reserves during mid-pregnancy provided significant benefit for increased resilience and immunity against worm infestations. This lends further support to adherence of industry control programs such as integrated parasite management in sheep which incorporates adequate nutrition for the successful control of worm infestations.

To support the adoption of this research by industry future work should address the following issues:
1. Effects on single bearing ewes
2. Cost analysis of supplementation suited to a range of pastures bases
3. Direct benefit to improved stocking rates,
4. On farm trials identifying its application on a larger scale and
5. Adaptation to a range of production systems and climatic environments

Conclusion

The project work described has provided evidence for a benefit from both prepartum FS and protein supplementation for effectively improving maternal and neonatal survival and rearing success in twin-bearing Merino ewes grazing low quality pastures. These effects appeared to be mediated through changes in body reserves of fat and muscle. The effectiveness of supplementation indicates that twin-bearing ewes may be managed over the prepartum period at lower than current recommended industry targets without penalty to survival. The industry application of this approach is to better target prepartum supplement strategies to address key welfare issues related to the reproductive cycle of the ewe. Managing ewes with lower fat and protein reserves may enable sheep producers to reduce pasture requirements and increase stocking rate which, based on the relative costs of subsequent supplement strategies, may also increase enterprise profitability.

In addition, periparturient ewes were shown to be susceptible to worm infestations during late pregnancy and early lactation which adversely effected productivity in ewes and their lambs. Evidence that the immune response was compromised was indicated by a decline in circulating eosinophils. Aspects of the immune response, including circulating eosinophil count, were associated with lower WEC and worm counts prepartum. Increasing FS associated with greater tissue reserves of fat and protein provided a significant benefit to protective immunity prepartum, but this was completely lost as differences between FS groups in fat and protein reserves converged between groups during the postpartum period. Prepartum protein supplementation did not enhance protective immunity, nor did it have selective and beneficial effects in low FS group ewes. Taken together, these results indicate that greater fat and protein reserves of pregnant ewes mediated an increased immune response to worm infestations, with the increase being in proportion to the magnitude of differences in tissue reserves experienced during the prepartum period only.

Effects of worm infestations on production were in some cases greater in the low FS group and this highlights the benefit of providing adequate nutrition to reproductive ewes as part of an integrated management approach for the control of worm infestations. Nevertheless, all treatment groups across remained susceptible to infection which would have required anthelmintic treatment in a commercial situation.