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Nutrition for parasite management

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Abstract

Considerable experimental evidence suggests that supplementation with protein can enhance both immune responsiveness and resilience of sheep to infection with gastrointestinal nematode parasites. Practical application of this knowledge is an objective of the Australian Sheep Industry CRC. Field trials were carried out in NSW, WA and SA targeting the most susceptible classes of sheep, i.e., young weaner lambs and/or pregnant ewes. Improved nutrition during pregnancy to maintain a condition score of 3 may lower faecal egg count in ewes in late gestation and during lactation and, importantly for resilience to infection, may produce heavier lambs at weaning. Significant reductions in faecal egg count and improvement in liveweight of ewes and lamb survival were also obtained following short-term protein supplementation pre-partum and the beneficial effects persisted until weaning. Short-term, high-protein supplementation of young weaners was generally beneficial in terms of improving resilience to parasite infection and enhancing liveweight gain and wool growth, but did not always result in lower parasite burdens. The cost-effectiveness of these strategies appears dependent on the level of parasite infection encountered together with the price of supplement used. Environmental factors in the particular region also clearly play a role through influences on forage availability and pasture infectivity.

Introduction

Infection with gastrointestinal nematode parasites remains one of the greatest problems for sheep production in many regions of Australia due to the widespread development of anthelmintic resistance (Besier and Love, 2003). In seeking alternative, non-chemical options for control, the strategic use of nutritional supplements, particularly protein, has frequently been proposed as a means to enhance immunity and resilience to infection. Substantial scientific evidence supports this proposal as shown by the recent Australian Sheep Industry CRC technical review of this area (see Knox et al., 2003). However, this workshop concluded that little practical implementation of these scientific findings had occurred in the Australian sheep industry (Steel et al., 2003).

Here we report summarised results from two years of study undertaken to establish nutritional strategies for worm management in meat and wool sheep production environments with distinct differences in management options and parasite epidemiology. On-farm trials were established in three regions; those in the dry summer environments of Mediterranean Western Australia and the winter rainfall zone of South Australia were principally focussed on protein supplementation of young weaners, but also examined the influence of condition score in pregnant ewes. Those in the summer rainfall zone of NSW. examined short-term protein supplementation of ewes in late pregnancy and of lambs in the early post-weaning period.

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Mediterranean Zone

Supplementing lambs after weaning 2003–04

A trial was established on a commercial farm near Kojonup, WA, which was co-located with an existing Australian Wool Innovation Lifetime Sheep (AWI-LTS) experiment, investigating the effects of different nutritional levels of ewes on the performance of their progeny over the following years (Ferguson et al., 2004).

Ewes were confirmed pregnant by ultra-sound scan with approximately 50% carrying twins. They were run in two flocks each of about 350 ewes, and paddock-fed grain from day 70 of pregnancy at levels to achieve mean flock condition scores (CS) of either 2 or 3; they lambed in late July/early August 2003.

Lambs were weaned in early October and then allocated to eight treatment groups in a 2 × 2 × 2 factorial design (i.e., CS 2 or 3 ewe × supplemented for six weeks or not supplemented × drenched or not drenched), each group comprising approximately 100 lambs with even allocation of single and twin lambs to allow for analysis of the effects of parity and for losses over the monitoring period of at least 18 months from weaning. Severe worm infection required all undrenched lambs to be salvage drenched six weeks after weaning and results for these lambs are not presented here.

There was a 6 kg difference in mean conceptus-free liveweight between the two CS groups at lambing and CS3 ewes maintained a heavier liveweight until some time after weaning. Prior to lambing, faecal worm egg counts (FWEC) indicated very low levels of nematode parasite infection in both flocks. There was no significant effect of CS on ewe FWEC after lambing when ewes ran as a single flock. Mean FWEC were significantly lower ($P < 0.001$) in single- compared with twin-bearing ewes. More sampling was planned, but a drench was necessary prior to weaning due to extensive scouring in both CS groups in mid-September.

At weaning, lambs from CS 3 ewes were heavier than those from CS 2 ewes (30 kg vs. 24 kg). Supplementation with 330 g/head/day of feed pellets (18% crude protein) for six weeks improved liveweight of both CS 2 and CS 3 lambs by 2.5 kg and this difference persisted until shearing in March 2004. These differences were maintained throughout the dry summer and early autumn period. Thereafter there was a weight loss in all groups until green feed became available in June/July when all groups started to gain weight. By August 2004 there was no significant difference in the mean liveweight of supplemented and unsupplemented weaners from CS 2 ewes, but supplemented animals from CS 3 ewes were still significantly heavier by 2 kg ($P < 0.05$) than the unsupplemented group. By April 2005, there were no significant differences attributable to supplementation in either CS group, but animals from CS 3 ewes remained significantly heavier than those from CS 2 ewes. There were no significant differences in FWEC between the groups throughout the observation period.

Mean dag scores of lambs during the winter months were generally similar in all groups until early August 2004 when there was a trend for unsupplemented lambs to have the higher dag scores. However, at this time the difference in dag score between supplemented and unsupplemented groups was significant only for the lambs of CS 3 ewes.

Antibody analysis of animals from the two nutritional regimes showed that parasite-specific total immunoglobulin levels increased after weaning in November, peaked in December and declined over the January to April 2004 period, but then rose substantially in late June. Supplemented lambs consistently had higher mean total immunoglobulin levels than unsupplemented lambs throughout, but there was considerable within-group variation and differences were not significant.

Supplementing lambs after weaning 2004–05

A second trial was established on the same commercial farm near Kojonup, WA. About 948 ewes were managed as two flocks by the AWI-LTS project: high condition-score (329 ewes mated to wool sires;

138 mated to meat sires) and low condition-score (331 ewes mated to wool sires; 150 mated to meat sires). Of these, approximately 619 had single lambs and the rest twins, split roughly equally among the four condition/sire groups. Lambs were identified according to ewe score (high/low), sire type (meat/wool) and birth type (single/twin), and were weaned, drenched, weighed, worm egg counted and allocated to treatment groups on 16 November 2004.

In October 2004, Feed On Offer (FOO) was high (>1500 kg/ha) but dried off quickly as the month progressed. The weaning drench was delayed, partly due to farmer request, resulting in relatively little exposure to parasites subsequently. The post-weaning pasture had been grazed with relatively wormy sheep (ewes and lambs), but tracer-weaners revealed little contamination. The season dried off prematurely and the late "weaning drench" precluded the requirement for another "summer drench" since FWEC remained low from then onwards. Ongoing analysis of pasture quality and availability and the animal feed requirements for growth by the GrazFeed decision support package (Freer et al., 1997) indicated the need for supplementation of weaners to commence at weaning as green herbage started to senesce.

Ewes

Mean liveweights of CS 3 ewes were 6–7 kg heavier than CS 2 ewes from May onwards. Mean FWEC of the CS 2 ewes in late gestation were significantly higher than for CS 3 ewes, but following a drench treatment of all animals in late May there was no significant difference in FWEC between the groups on any other occasion.

Meat lambs

At weaning, the 236 progeny were randomly allocated to four groups (High/Fed, High/Not fed, Low/Fed, Low/Not fed) of just under 60 per group ("High" = birth mother maintained at score 3 during pregnancy vs. 2 for "Low"). The four groups were shorn and then managed as two feeding groups (Fed/Not fed) for 47 days from 16 November through to the first week of January. The supplement was 375 g/head/day of a 60% canola meal 40% barley pellet to provide a high input of bypass protein

About three weeks before supplementary feeding commenced, lambs from CS 3 ewes were on average 3.2 kg heavier than those from CS 2 ewes (31.6 kg vs. 28.4 kg). After four weeks of supplementary feeding, Fed groups had gained 3.6 kg more ($P < 0.001$) than their Not-fed counterparts which maintained (CS 2) or lost weight (CS 3). By mid-February 2005, 17% of the Fed group and 23% of the Not-fed group of meat lambs had been placed in a feedlot for finishing. By early April, all lambs had been placed in the feedlot and mean liveweights of the four groups were almost identical.

Wool lambs

The 236 progeny were treated identically to the meat sheep, but were shorn in January 2005 after the feeding period. They were also allocated to four groups and managed as two feeding groups. Both meat and wool lambs were not set-stocked, but rather rotated twice weekly among five small paddocks to ensure equal exposure to parasitism.

When feeding commenced, wool lambs from CS 3 ewes were 3.1 kg heavier than those from CS 2 ewes (26.2 kg vs. 23.1 kg). Survival of wool lambs was significantly affected by both supplementation and maternal condition score; deaths in Fed groups averaged 12% compared to 25% in Not-fed groups and progeny of CS 3 ewes survived better than those of CS 2 ewes. Liveweight change of survivors from late October to mid-February, which included the supplementation period, showed that feeding increased liveweight gain by an average 3.4 kg ($P < 0.001$) across the two CS groups. Mean greasy fleece weight of the Fed group was 1.76 ± 0.04 kg compared to 1.56 ± 0.04 kg for the Not-fed group; the difference was statistically significant ($P < 0.001$). Clean fleece weight was significantly higher by 168 g in CS 3 than CS 2 offspring and was significantly increased by 137 g by supplementary feeding. Mean fibre diameter of wool was similar for Fed and Not-fed groups at 18.89

± 0.16 and 18.99 ± 0.13 µm respectively.

There was no difference in FWEC between meat and wool lamb groups during or following the supplementation period. In both meat and wool sheep, larval differentiation showed that *Ostertagia* spp. were predominant after drenching with Rametin/Combo; *Trichostronylus* spp. were present before drenching.

In summary, these trials over two successive years showed a good liveweight and wool growth response to short-term protein supplementation of weaners as pastures diminished in quality in late spring/early summer, and improved liveweight persisted through to the following winter. Although there was good evidence of improved resilience with an economic benefit when parasite exposure was high, there were no apparent effects on parasite burden or longer term benefits in terms of enhanced resistance to infection as hoggets encountered the following year's rise in pasture infectivity.

Winter Rainfall Zone

Supplementing lambs after weaning 2004–05

In 2004, we extended our trials to include the AWI-LTS experiment being undertaken by PIRSA-SARDI on a commercial property near Kingston, SA (described by Gillam, 2005). The protocol for this AWI-LTS trial was similar to that described above. After lambs were weaned on 21 September 2004, supplementary feeding of single male weaner lambs from each maternal condition score group commenced in early November when pasture conditions had deteriorated to a level unable to sustain a reasonable growth rate. A pelleted canola meal/barley pelleted supplement (30.7% crude protein) was offered from a self-feeder for six weeks to the two maternal groups and a further two groups were maintained on pasture alone as controls. There were 70–80 lambs in each of the four groups and monitoring continued until October 2005.

Mean FWEC of CS 3 ewes were lower at marking, mid-lactation and weaning than in CS2 ewes, the difference being statistically significant on the latter two occasions (see Table 1). Within each CS group at marking, FWEC were significantly higher in twin- than single-bearing ewes, but by weaning this difference was no longer significant. At weaning, CS3 ewes in single- and twin-bearing groups each had significantly lower FWEC, and overall were approximately 70% lower than CS2 counterpart groups.

Table 1. Summary of statistical analysis of ewe faecal worm egg counts in high (CS 3) and low (CS 2) condition score ewes in the Winter Rainfall Zone. Differences were considered significant at $P < 0.01$; n/s. non-significant (Carmichael et al., unpublished).

	Marking (4 August)	Mid-lactation (2 September)	Weaning (21 September)
High CS vs. Low CS overall	n/s (180 vs. 226)	$P < 0.01$ (184 vs. 278)	$P < 0.01$ (91 vs. 292)
High CS single vs. High CS twin	$P < 0.01$ (143 vs. 250)	n/s ($P = 0.017$) (163 vs. 221)	n/s ($P = 0.045$) (77 vs. 120)
Low CS twin vs. High CS twin	n/s (314 vs. 250)	n/s (260 vs. 221)	$P < 0.01$ (346 vs. 120)
Low CS single vs. High CS single	n/s (174 vs. 143)	$P < 0.01$ (289 vs. 163)	$P < 0.01$ (261 vs. 77)
Low CS single vs. Low CS twin	$P < 0.01$ (174 vs. 314)	n/s (289 vs. 260)	n/s (261 vs. 346)

The 140 supplemented lambs were fed from a self feeder from 8 November until 20 December; the pellets were highly palatable and a total 1729 kg (average 294 g/head/day) was consumed. In single lambs at weaning, progeny of CS3 ewes had lower faecal egg counts than CS2 ewes; for *Nematodirus* spp. the respective mean egg counts were 114 and 198 eggs per gram (epg), and for *Trichostrongylus/ Ostertagia* spp. the respective counts were 259 and 437 epg.

After three weeks supplementation, FWEC were reduced by 31% (392 vs. 561 epg) in supplemented lambs and after six weeks by 51% (1273 vs. 2605 epg). The reduction in FWEC as a response to six weeks' supplementation was greater in weaners from CS 2 ewes (63%) than in those from CS 3 ewes (35%). There were no significant differences in the FWEC between weaners originating from ewes of CS 2 or 3. All lambs were drenched in December 2004 at the conclusion of the supplementation period. Further FWEC in mid-March and late October 2005 showed no differences between groups.

When feeding commenced, the lambs from CS 3 ewes were 2.7 kg heavier than those from CS 2 ewes (27.8 kg vs. 25.1 kg). After six weeks of supplementation , lambs from CS 3 and 2 ewes had both gained 2.6 kg and were 4.1 and 3.3 kg, respectively, heavier than their controls, which lost weight (–2.1 and –1.7 kg, respectively) over this period. This difference between supplemented and control lambs was maintained until shearing in mid-March 2005, but by late October 2005 the difference had reduced to around 2 kg.

Lambs supplemented with canola-meal based pellets grew significantly more greasy ($P = 0.0012$) and clean wool ($P = 0.0008$) than unsupplemented weaner lambs (Table 2). Likewise, FD was significantly broader in the supplemented lambs compared to the control lambs ($P < 0.0001$; Table 2). Lambs born to ewes maintained at CS 3 throughout pregnancy had greater GFW ($P < 0.0001$), CFW ($P < 0.0001$) and FD ($P = 0.0040$) than lambs born to ewes that lost condition throughout pregnancy (Table 2). There was no interaction between supplementary feeding and ewe condition during pregnancy for any of the wool measurements.

Table 2. Number (N) of supplemented and unsupplemented (control) lambs fleece sampled and their greasy fleece weights (GFW), clean fleece weights (CFW) and fibre diameter (FD) in the Winter Rainfall Zone (least square means ± SEM) (Carmichael et al., unpublished).

	N		GFW		CFW		FD	
	High	Low	High CS	Low CS	High CS	Low CS	High CS	Low CS
Control	64	65	2.35 ± 0.058	2.05 ± 0.058	1.69 ± 0.044	1.49 ± 0.044	16.5 ± 0.14	16.1 ± 0.14
Supplement	71	66	2.61 ± 0.055	2.17 ± 0.058	1.90 ± 0.041	1.58 ± 0.043	17.1 ± 0.13	16.6 ± 0.13

It is concluded that nutritional supplementation in this Winter rainfall zone during the time of declining quality of pasture in the presence of continued challenge from worms can reduce FWEC significantly and very rapidly, and that the effect may be greatest in the more stressed, less hardy weaners from the CS 2 ewes. Ewe condition probably played no direct part in the parasitological interactions of the lambs. Production responses clearly showed that lambs from higher CS ewes have an initial weight advantage at weaning that may reflect both their greater ability to control worm populations and the better nutrition provided by the ewe up to weaning. Liveweight and wool production responses to supplementary feeding in the post-weaning period indicate that both increased resilience to pathological responses to infection in addition to enhanced resistance to parasites as demonstrated by reduced FWEC were involved in the effects engendered by improved nutritional management.

Summer Rainfall Zone

Supplementation of pregnant ewes 2003–04

A field trial was established on a commercial organic farm near Uralla in Northern NSW. From pregnancy scanning in mid-August 2003, 565 Merino ewes were grazed as a single flock and were regularly monitored for liveweight, faecal egg counts and body condition score. Seven weeks pre-partum the ewes were stratified on the basis of body condition score and parity into two equal groups, one group was supplemented with 220 g/head/day copra meal pellets offered in three equal amounts weekly for six weeks and the other group was unsupplemented. In addition, 50 ewes from each group were stratified on the basis of condition score into two sub-groups consisting of high and low performers for closer monitoring. Lambing commenced on 9 October and lambs were identified to mother at birth and evaluated at marking, between marking and weaning, at weaning and for three months after weaning.

Good seasonal conditions in late winter and spring led to abundant FOO prior to and after lambing. As a result of the abundant feed meeting all nutritional requirements of the ewes, there were no significant effects of supplementation on faecal worm egg counts and liveweights of ewes with all ewes being in CS > 3 and gaining weight at a similar rate prior to lambing and during lactation. There was also no effect of maternal supplementation on the weight of lambs at birth, marking, weaning or during the post-weaning period. Similarly, there were no clear-cut effects of supplementation on measured blood cell parameters in monitor groups of ewes or lambs.

Supplementation of pregnant ewes and weaner lambs 2004–05

After shearing and pregnancy scanning in July 2004, 368 fine-wool Merino ewes were stratified on liveweight and parity into two groups and one group supplemented with cottonseed meal (CSM) at 200 g/hd/d for six weeks prior to lambing. Within these groups, the 25 single-bearing and twin-bearing ewes of greatest liveweight (HIGH) and the 25 with lowest liveweight (LOW) were identified. For the HIGH and LOW ewes, liveweights and FWEC were monitored and blood collected at intervals for immunological assessment. The groups were allocated to separate pasture plots and were changed to the alternate pasture plot every three to four days to ensure similar access to available pasture and free-living nematode larvae. Pasture quality was monitored regularly and, based on GrazFeed estimates of animal requirements, all ewes were supplemented with lupins (200 g/head/day) to maintain maternal weight from four weeks prior to lambing.

Immediately prior to lambing, all ewes were drenched and moved to a newly divided paddock with separate group-lambing plots where they remained until lambs were marked and tagged to groups in early November. Lambs were weighed at marking (week 13), between marking and weaning and at weaning. After weaning on 2 February 2005 (week 27), 100 ewe offspring from each maternal group were drenched and moved to another pasture area.

On 15 February, 30 Border Leicester × Merino cross (BLMX) ewe lambs were drenched and moved to the same area. When pasture conditions declined in Autumn, half of the weaner lambs from each maternal group were separated and fed 200 g/day CSM supplement for eight weeks from 28 April to achieve a liveweight difference between groups (according to GrazFeed calculations). Monitoring continued until shearing in September 2005.

Ewes

Supplementation with CSM increased liveweight of ewes by 3–4 kg prior to lambing and this effect persisted but declined in the period up to weaning. Parity affected liveweight only prior to lambing and weight grouping effects were maintained only until marking. Interactions between these factors were not consistently observed at individual samplings. There was, however, a significant interaction between time of sampling, supplementation, parity and weight group (P = 0.002) from repeated measures analysis of variance (ANOVA). In single-bearing ewes, the difference between the HIGH and LOW group ewes was not evident after marking whereas the effect of supplementation persisted until weaning. For twin-bearing ewes, the unsupplemented LOW ewes remained lighter until weaning whereas at marking the unsupplemented HIGH ewes converged with both the supplemented LOW and HIGH groups.

Mean FWEC in supplemented and control ewes are shown in Fig. 1. *Haemonchus* spp. (73–87%) was the predominant nematode species present along with *Trichostrongylus* spp. (9–20%) and *Ostertagia* spp. (2–11%). Supplementation with CSM reduced FWEC during supplementation (weeks 4 and 5) and this effect persisted to weeks 13 and 27. Twin-bearing ewes had higher FWEC at week 13, but no effect of weight score at any individual sampling. Repeated measures ANOVA showed a highly significant (P < 0.0005) effect of supplementation over time but no effects (P >0.05) of parity or weight score or any interactions between these factors with time or supplementation.

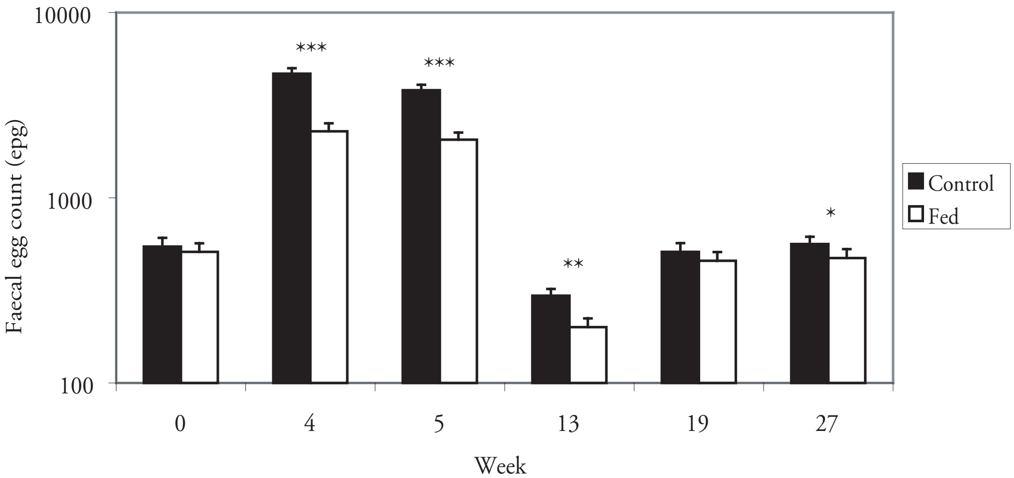

Fig. 1. Faecal worm egg counts of ewes supplemented with cotton seed meal (Fed) for six weeks pre-partum and unsupplemented controls in the Summer Rainfall Zone. (*** P < 0.001; ** P < 0.01; * P < 0.05) (M.R. Knox and colleagues, unpublished).

Mean total anti-parasite immunoglobulin levels in plasma of ewes from the start of supplementation until weaning did not show a significant difference due to supplementation, but there were significantly higher levels (P < 0.05) in the HIGH compared to the LOW weight group at 4, 5 and 19 weeks after supplementation commenced. Parity had a significant effect on antibody level at weeks 13 and 27; in repeated measures ANOVA, there was a significant interaction of time with supplementation.

Weaner lambs

There was no significant effect of maternal supplementation observed on lamb liveweight (average 24.3 kg) or FWEC (average 282 epg) at weaning on 2 February 2005. Drought conditions emerged from March 2005 with rapid deterioration in green herbage occurring from early April when drought rations (100–150 g/day faba beans or lupins) were commenced to maintain liveweight of all weaners according to GrazFeed recommendations. No differences in FWEC attributable to CSM supplementation of Merino or crossbred weaners were evident throughout the observation period including the period five weeks after a single artificial challenge infection of 8000 *H. contortus* larvae. Supplementation with CSM improved liveweight of weaners by 3 kg by the end of the feeding period in late June and this difference persisted but declined to around 2 kg by the conclusion of the trial in September 2005. Supplementation with CSM increased fleece weights of Merino weaners by 11–12% but there was no significant change in wool fibre diameter at shearing in mid-September. Supplementation of crossbred weaners with CSM had no significant effect on fleece weight (10% increase) or fibre diameter.

Conclusions

Nutritional supplementation strategies have been developed for sheep production systems to minimise the impact of gastrointestinal parasites by enhancing both immune responsiveness and resilience to infection. Field trials showed that nutritional strategies were feasible for pregnant ewes and weaners under commercial conditions in the Mediterranean rainfall zone of southern WA, the winter rainfall zone of SA and the summer rainfall zone of northern NSW.

Improved nutrition during pregnancy to maintain a condition score of 3 may lower FWEC in ewes in late gestation and during lactation and, importantly for resilience to infection, can produce heavier lambs at weaning. Significant reductions in faecal egg count and improvements in liveweight of ewes and lamb survival can also be obtained following short-term protein supplementation pre-partum and these beneficial effects may persist until weaning.

Short-term, high-protein supplementation of young weaners as a strategy to manage parasitism and ameliorate production losses was generally beneficial in terms of improving resilience to parasite infection as shown by enhanced liveweight gain and wool growth, but did not always result in lower parasite burdens. The cost-effectiveness of this strategy appeared dependent on the level of parasite infection encountered together with the price of supplement used. Environmental factors in the particular region also clearly play a role through influences on FOO and pasture infectivity.

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