Animal production from pasture-fed and mixed forage grazing systems

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Abstract: *Forage and pasture-fed production systems represent the majority of sheep and cattle enterprises in Australia. The current paper reviews a range of pasture-fed and mixed species forage grazing systems, examining average daily gain, rumen efficiency, reproduction outcomes and health aspects of meat produced. Average daily gain was higher when lambs grazed mixtures of forages containing brassica, cereal and legumes with higher dry matter on offer compared with a single species brassica. Rumen pH was also higher when sheep grazed forage mixes containing cereals compared with brassica and legumes which could have been related to improved fibre degradability and rumen efficiency. In separate studies, the amount of healthy omega-3 fatty acids and the proportion of male lambs born was higher when sheep were fed rations containing high omega-3 forages compared with grains. These studies provide evidence supporting the use of pasture and mixed forages in maximising productivity in a range of sheep and cattle enterprises. Important aspects to consider are species selection, grazing management and matching available forage to production goals.*

Key words: rumen fermentation, health benefits

Introduction

Forages play a major role in sheep and cattle enterprises, with the majority of meat and wool in Australia produced from pasture-fed systems. The quality of forages produced on farm can be variable and a significant amount of research has been conducted to maximize the quantity and quality of pasture available to improve the efficiency of production. As an example, annual forage crops are commonly used to provide high quality fodder for livestock during typical autumn and winter feed-gaps in the south-east of Australia (Moore *et al.* 2009) and to provide benefits through rotations in cropping systems (Kirkegaard *et al.* 2008). Typical annual forage crops comprise single species cereals, for example oats or dual-purpose wheat (McGrath *et al.* 2021) or forage brassica or legumes. More recently, mixed species crops have been used for animal grazing, which have several potential benefits including optimising mineral supply for sheep and cattle, using specific species as a break crop for crop disease control, improving ground cover and suppressing weed growth as well as increasing soil carbon (Malezieux *et al.* 2009).

In addition to the use of these forage crops for increasing meat or wool production, there are several other potential benefits from pasture-fed systems, including improving health attributes of meat and altering reproductive outcomes. Forages are high in omega-3 fatty acids (Clayton *et al.* 2024) and meat from grass-fed production systems is also higher in these healthy fatty acids that can reduce the risk of cardiovascular disease and other inflammatory disorders in humans (Simopoulos 1999). In addition, the proportion of male lambs was higher when ewes were fed forage-based diets compared with grain around joining (Clayton *et al.* 2016a; Clayton *et al.* 2016b), which highlights the importance of nutrition on reproduction. The following review outlines the effect of forage systems on several production outcomes in sheep and cattle, including weight gain and rumen efficiency, health attributes of meat for humans and reproduction in sheep.

Methods, Results and Discussion

The studies presented in the current review were conducted by the NSW Department of Primary Industries at the Wagga Wagga Agricultural Institute over a number of years. The main outcomes and implications for forage-fed production systems are presented.

Mixed forage species – average daily gain and rumen efficiency

A total of 96 Dorset x Border Leicester x Merino lambs (11 months of age, 48.5 ± 0.32 kg) were allocated to one of four forage treatments (n = 24 per treatment) including:

1. A single species brassica (Br) comprising canola (*Brassica napus* L. cv. Hyola 970)
2. A brassica + cereal mixture (B+C) comprising canola, tillage radish (*Raphanus sativus*), purple top turnip (*B. rapa* subsp. *rapa*), wheat (*Triticum aestivum* L. cv. Ilabo) and cereal rye (*Secale cereale* L. cv. Vampire)
3. A brassica + legume mixture (B+L) comprising canola, tillage radish, purple top turnip, common vetch (*Vicia sativa* subsp. *sativa*) and arrowleaf clover (*Trifolium vesiculosum* cv. Zulu II)
4. A brassica + cereal + legume mixture (B+C+L) comprising all species above.

The four treatments were arranged in a randomised complete block design with each treatment replicated four times with a total of 16 plots (each 50 x 50 m). The crops were sown in the first week of April 2023 with a tyned seeder (0.17 m row spacing) and grazing commenced 79 days after sowing when there was greater than 1600 kg DM/ha on offer in all plots. Grazing occurred over 35 days and liveweight was determined prior to and after grazing following an overnight fast. Samples of rumen fluid were also collected for the determination of pH and volatile fatty acids as described previously (Clayton *et al.* 2024b).

Mean dry matter on offer from day 0–21 was highest for the B+C+L forage treatment compared with B+C, B+L or Br control ($P < 0.05$) and decreased for all plots over the period of grazing (Fig. 1). Mean average daily gain (ADG) was lower for female, but not male, lambs grazing the Br only plots compared with any species mix (Fig. 2) which was related to a lower dry matter on offer. Rumen pH was lower 35 days after grazing commenced when sheep grazed Br only and was highest when sheep grazed the B+C or B+C+L treatments compared with other treatments (Fig. 3).

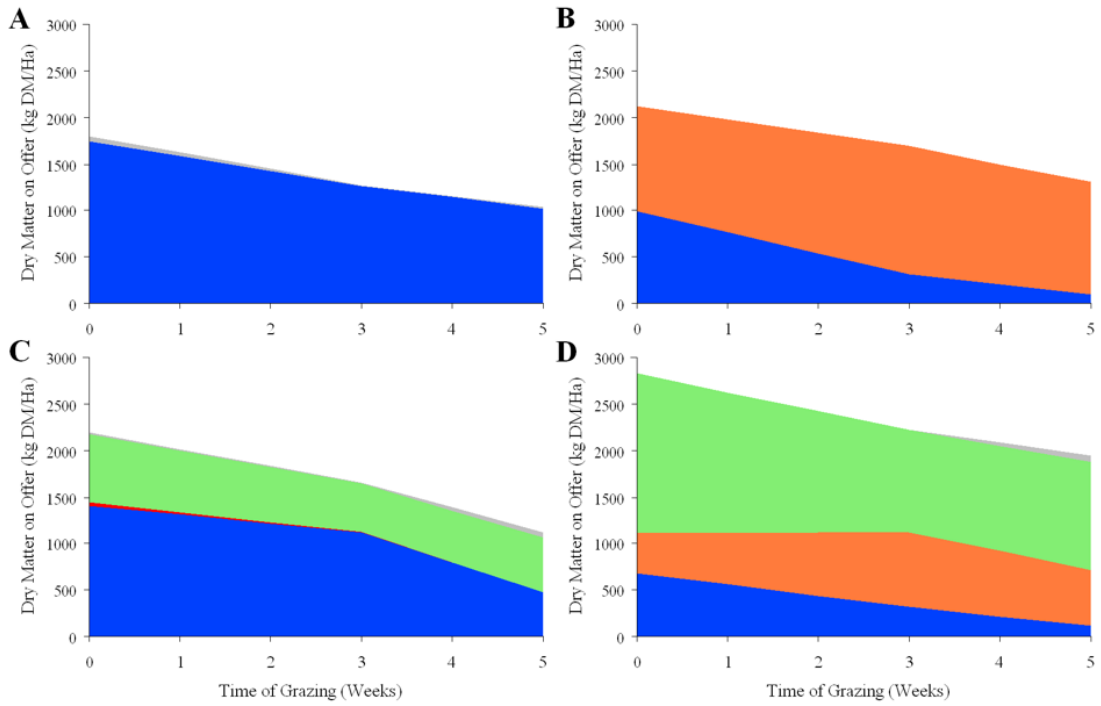

Figure 1. Dry matter on offer (kg DM/ha) of individual species including brassica (■), cereal (■), legume (■) or other species (■) for plots containing A) Brassica only or a mixture of B) Brassica + Cereal, C) Brassica + Legume or D) Brassica + Cereal + Legume. Data from (Clayton *et al.* 2025)

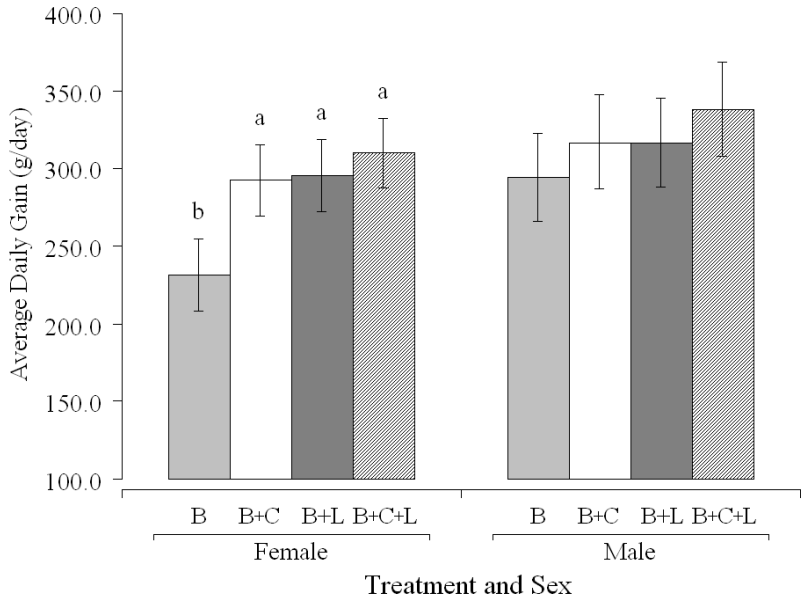

Figure 2. Average daily gain (ADG, g/hd/day) for female and male lambs from day 0–21 of grazing plots containing Brassica only (Br) for 21 days or a mixture of Brassica and Cereal (B+C), Brassica and Legume (B+L) or Brassica, Cereal and Legume (B+C+L) for 35 days. Different superscripts between fodder species (within Sex) indicate significant differences ($P < 0.05$). Data from (Clayton *et al.* 2025).

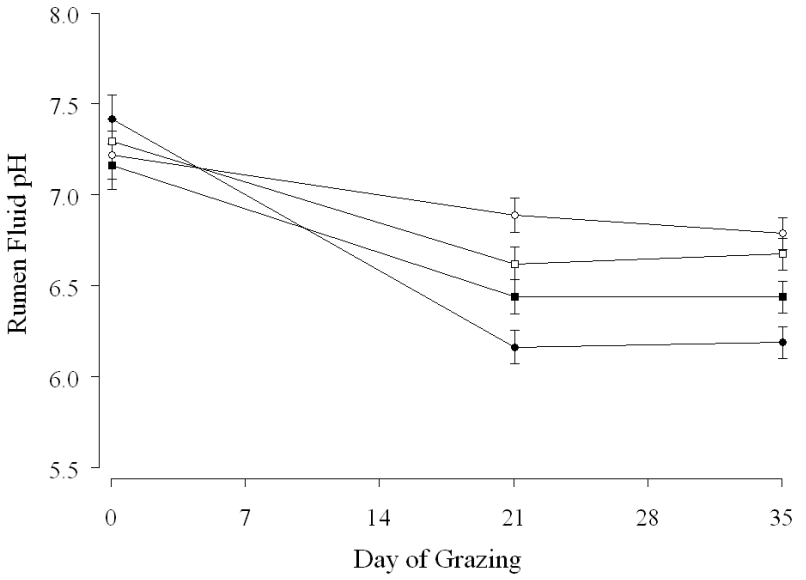

Figure 3. Mean rumen pH when lambs grazed plots containing Brassica only (●) or a mixture of Brassica and Cereal (○), Brassica and Legume (■) or Brassica, Cereal and Legume (□) for 35 days. Values are least squares means ± standard error of the least squares means. Data from (Clayton *et al.* 2025).

The lower rumen pH when lambs grazed the Br only could have been associated with lower fibre degradability and sub-acute rumen acidosis (SARA). The higher ADG in female lambs grazing forage mixtures compared with the Br only control was related to a higher dry matter on offer. Further research should determine whether the lower pH observed when sheep grazed brassica or brassica and legumes compared with cereal mixes is associated with sub-acute rumen acidosis and reduced fibre degradation and forage energy utilisation.

Omega-3 fatty acids in forages and grass-fed beef and lamb

A series of studies examining the amount of omega-3 in different forage species and the effect of grass and grain feeding on omega-3 in sheep and cattle were conducted. These studies highlight factors that affect the amount of omega-3 in forages

and importance of diet on omega-3 in sheep and cattle.

Omega-3 in forages. A glass house pot trial examined the amount of omega-3 in four commonly grazed forages, including:

- oats (*Avena sativa* L. cv. Eurabbie),
- annual ryegrass (*Lolium multiflorum* L. cv. Rambo),
- phalaris (*Phalaris aquatica* L. cv. Holdfast GT), and
- subterranean clover (*Trifolium subterraneum* L. cv. Coolamon)

Seeds were sown into polyvinyl chloride pots (100 mm internal diameter, 300 mm height) containing approximately 3100 g of oven-dried Red Kandosol soil watered to approximately 80% of field capacity. Plants were harvested at seven stages of maturity according to the Zadoks scale for oats and stage of development in relation to vegetative or reproductive growth for phalaris and ryegrass corresponding to early vegetative, late vegetative, stem elongation, boot, anthesis, soft dough and ripening or relative to day of flowering in clover, on days 66, 84, 102, 115, 126 (flowering), 142 (seed set) and 162. Forage quality and fatty acid concentration was determined using procedures described previously (Clayton *et al.* 2024a).

The proportion of the omega-3 fatty acid C18:3n-3 was highest in clover compared with any other species and higher in ryegrass and phalaris compared with oats. The proportion of omega-3 decreased with increasing stage of maturity for oats (13.9 ± 0.86 vs 64.3 ± 0.68), ryegrass (17.3 ± 0.86 vs 68.2 ± 0.65) and phalaris (21.6 ± 1.63 vs 65.1 ± 0.79) but not to the same extent for subterranean clover (41.5 ± 1.38 vs 57.4 ± 0.79, Fig. 4). The proportion of omega-3 was positively correlated with the crude protein (CP) content of plant material; however, omega-3 was lower for subterranean clover compared with oats, ryegrass and phalaris at similar CP concentrations.

The positive relationship between CP and omega-3 was likely due to a positive effect of CP on the growth of leaf material, as omega-3 is predominantly found in leaf chloroplasts. While the CP content remained higher for clover compared with other species examined, this did not translate to a higher proportion of omega-3 for any given CP. Grazing forages at earlier stages of maturity and maximising the amount of crude protein available for growth will increase the amount of omega-3 in plant material. The availability of this omega-3 for incorporation into meat and milk should be examined.

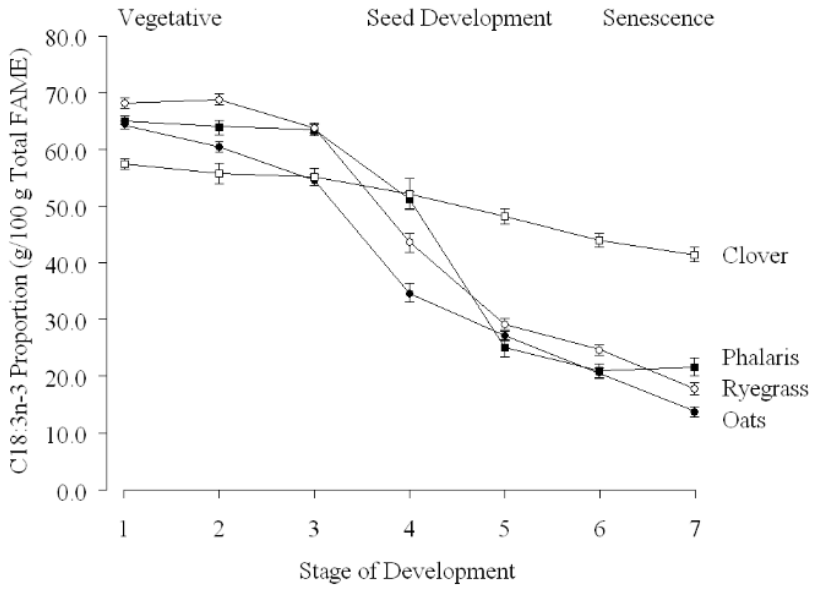

Figure 4. Mean proportion of α-linolenic acid (C18:3n-3) for oats (●), ryegrass (○), phalaris (■) and clover (□) over different stages of development. Values are least squares means ± standard error of the least squares means. Data from (Clayton *et al.* 2024a).

Depletion of omega-3 with grain. The depletion of omega-3 following the consumption of different grain types compared with lucerne was examined in Border Leicester x Merino ewes (44.3 ± 0.55 kg). The concentration of omega-3 fatty acids was determined in plasma collected from ewes prior to grain feeding and again after 1, 3, 5, 7, 14 and 21 days of consuming rations based on wheat, barley, oats or lupins in a grain:lucerne mix of 70:30 (n = 5 per dietary treatment). Feeding and analytical procedures have been described previously (Taylor and Clayton 2023).

The proportion of C18:3n-3 decreased rapidly after the introduction of grain and was significantly ($P < 0.05$) lower when sheep were fed any grain compared with lucerne three days after the commencement of feeding (Fig. 5). The depletion of omega-3 was greater after five days for oats and wheat compared with barley and lupins.

The rapid depletion of plasma omega-3 upon grain feeding indicates a lower availability for incorporation into tissues in growing sheep following short-term changes in diet. The effect of these short and long-term changes on long-chain omega-3 accumulation in meat and reproductive tissues warrants further investigation.

Omega-3 in grass-fed and grain-fed beef. If the total eicosapentaenoic acid (EPA) + docosahexaenoic acid (DHA) is greater than 30 mg per 135 g serve of beef, this can be considered a 'source' of omega-3 according to Food Standards Australia and New Zealand. The level of omega-3 in beef was determined from cattle either grass-fed in a pasture-fed assurance scheme or grain feed in a feedlot for approximately 90 days at three times of the year (winter, spring and summer). The total concentration of EPA + DHA was determined using procedures described previously (Clayton *et al.* 2024c).

The total EPA + DHA in beef declined from winter to spring and summer and was lower in beef from a grain-fed versus pasture-fed production system at each collection (Fig. 6). Grass-fed beef collected in winter and spring and grain-fed beef collected in winter could be considered a 'source' of omega-3. Grazing and feeding strategies should be designed to maximise the amount of omega-3 in beef in order to consistently supply beef with healthy levels of these fatty acids over different seasons.

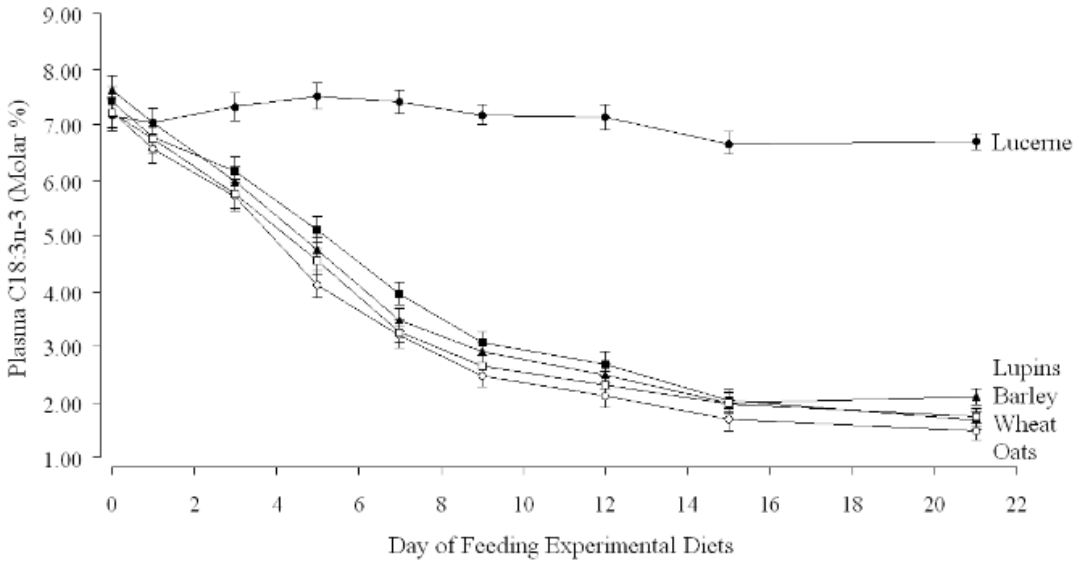

Figure 5. Mean change in plasma α-linolenic acid (C18:3n-3) following the consumption of rations based on lucerne (●), oats (○), wheat (■), barley (□) or lupins (▲) by ewes for 21 days. Values are least squares means ± standard error of the least squares means. Data from (Taylor and Clayton 2023).

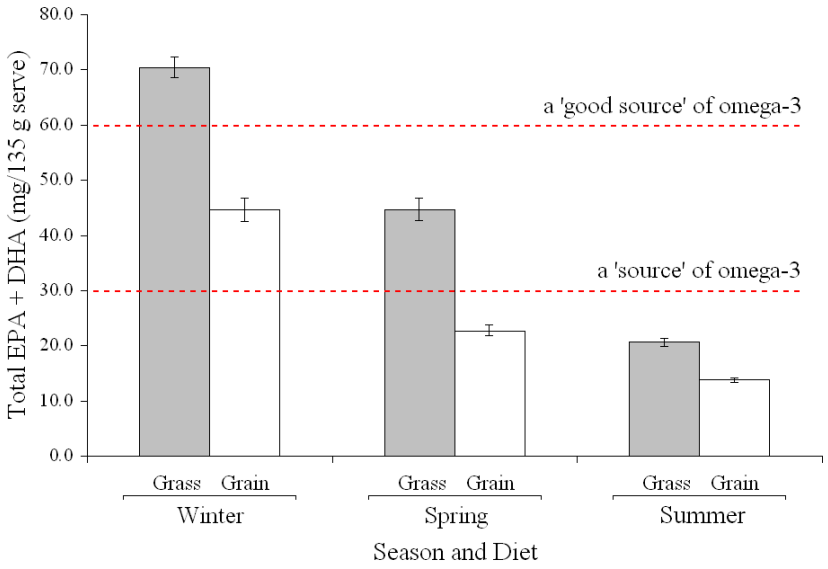

Figure 6. Total EPA + DHA (mg/serve) in the Longissimus muscle of grass-fed or grain-fed cattle collected at different times of the year.

Forages and grain-based diets – lamb sex ratio and intergenerational effects

A series of studies were conducted examining the effect of diets differing in omega-3 and omega-6 fatty acids on reproductive outcomes, including the sex ratio of lambs. These studies highlight the effect of diet fed at the time of conception on reproduction in ewes and the reproductive potential of their offspring.

Sex ratio of lambs. Two studies examined the effect of feeding diets either high in omega-3 or omega-6 to ewes around joining on the sex ratio of their lambs. Studies were conducted with Merino or Border Leicester x Merino ewes fed for six weeks prior to joining only or both six weeks prior to and three weeks following joining. A total of 320 Merino ewes (58.2 ± 0.34 kg) mated to Border Leicester (BL) rams and 304 BL x Merino ewes (64.8 ± 0.55 kg) mated to Dorset rams were enrolled in the study. The experimental design was a two x two factorial, with two dietary treatments (high omega-3 or high omega-6) similar to those reported previously (Gulliver *et al.* 2013) and two lengths of time of feeding (either pre-mating only or both pre- and post-mating). The high omega-3 diet was based on cereal or ryegrass silage while the high omega-6 diet was based on approximately 70% oat grain and 5.5% cottonseed meal (on a dry matter basis). All ewes of each breed grazed together from joining until lambing where the sex of lambs was determined (Clayton *et al.* 2016a; Clayton *et al.* 2016b).

The proportion of female lambs was higher when ewes were fed a high omega-6 compared with high omega-3 diet. These differences were similar when ewes were fed diets either pre-joining only or both pre- and post-joining, but the effects were greater for Merino compared with BL x Merino ewes (Fig. 7). If producers prefer male lambs, such as stud ram or prime lamb producers, there may be benefits from feeding ewes a diet high in omega-3 fatty acids around joining, whereas if producers prefer female lambs, such as self-replacing or stud ewe producers, feeding a diet high in omega-6 fatty acids may be more beneficial.

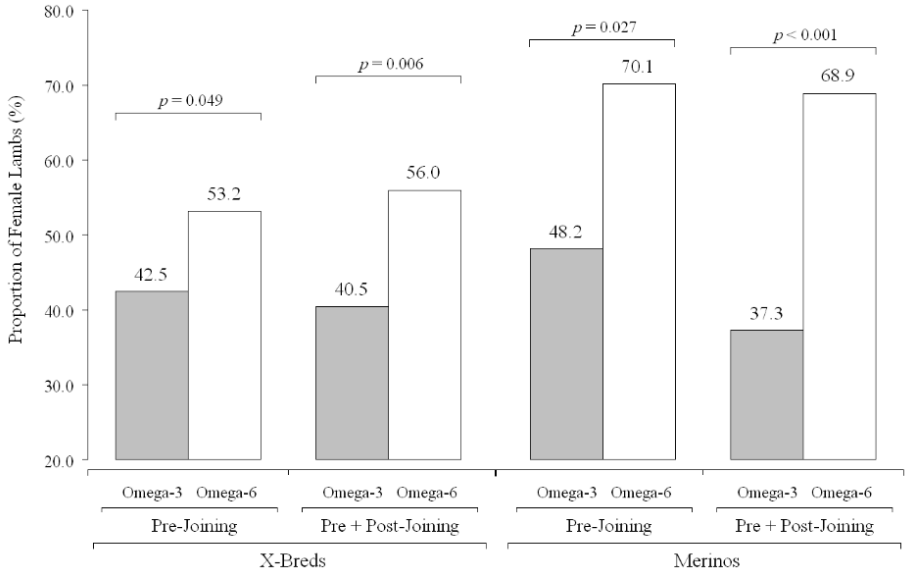

Figure 7. Mean proportion of female lambs when BL x Merino or Merino ewes were fed a diet high in omega-3 (shaded bars) or high in omega-6 (unshaded bars) fatty acids for approximately 40 days prior to mating (pre-mating) or 40 days prior to and 17 days following mating (pre and post-mating). Data from (Clayton *et al.* 2016a; Clayton *et al.* 2016b).

Intergenerational effects of diet – reproductive rate. The BL x Merino ewe lambs born from the Merino ewes described above were enrolled in a study to examine the intergenerational effects of the rations fed to their dams at joining (Clayton *et al.* 2017a; Clayton *et al.* 2017b). A total of 118 BL x Merino maiden ewes (12 months of age, 53.7 ± 0.46 kg) were included in the study. The experimental design was a two x two factorial, with two dietary treatments (high omega-3 or high omega-6) and two dam nutrition treatment groups (high omega-3 or high omega-6). All experimental procedures were the same as those described for dams, except ewes were mated with Poll Dorset rams. The pregnancy status, litter size and age of the fetus was determined by ultrasonography approximately 51–66 days after mating.

The mean number of fetuses per ewe pregnant or ewe joined (Fig. 8) and number of lambs born per ewe that lambed (1.58 ± 0.11 versus 1.28 ± 0.13, P = 0.023) was significantly higher when dams were fed the high omega-6 compared with the high omega-3 diet around mating. Reproductive rate was not differentially affected by the diet fed to the maiden ewes at joining. These results indicate that the reproduction rate of ewes may be affected by diet fed to their dams in the peri-conceptional period and could be associated with fetal programming.

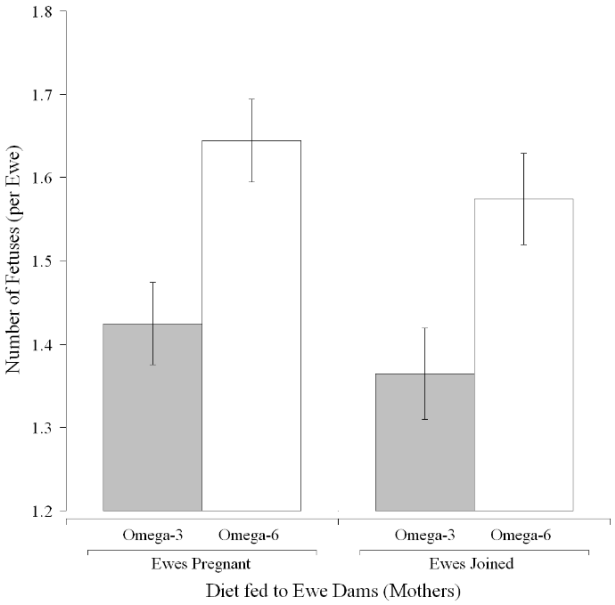

Figure 8. Mean number of fetuses at pregnancy scanning for BL x Merino ewes when their dams were previously fed a high omega-3 diet based on silage (shaded bars) or a high omega-6 diet based on oats and cottonseed meal (CSM, unshaded bars) around mating. Data from (Clayton *et al.* 2017a).

Conclusions

There are several potential benefits from feeding forage diets, particularly mixed forage species with high dry matter on offer. The effect of forages on ADG, fatty acids in meat and the reproductive outcomes of ewes indicate the significant influence of diet on sheep production. The key factor for

producers to consider is the selection of diet that suits their production system. For example, producers selecting for higher weight gain, a greater number of male lambs or increased health beneficial omega-3 fatty acids in meat, would benefit from grazing mixtures of high omega-3 forages. Potential negative effects of some forages should also be considered in more detail, for example the effect of brassica species on rumen pH, fibre degradability and rumen efficiency. Results of the current studies indicate that the incorporation of cereals with brassica or legume mixes may buffer the rumen environment and improve rumen efficiency.

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