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Demonstration of diet to influence lamb sex-ratio

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Abstract

Previous controlled trials conducted by NSW DPI at the Wagga Wagga Agricultural Institute indicated the proportion of female lambs was higher when ewes were fed oats and cottonseed meal (CSM) compared with silage around joining. The aim of the current project was to determine whether these results could be replicated in commercial sheep enterprises.

A series of 11 field trials were conducted in the Holbrook, Wagga and Orange regions of NSW over three years from 2016-2018. Ewes grazed pasture only (Omega-3), or pasture supplemented with grain (Omega-6), for four weeks prior to and two weeks following the commencement of joining. On one property, ewes in the pasture only group also received silage in addition to pasture. The sex ratio of lambs was determined at lamb marking.

The number of fetuses per ewe at pregnancy scanning was variable but higher when ewes were fed grain in addition to pasture (1.32 ± 0.01 fetuses/ewe scanned) compared with pasture only or pasture supplemented with silage (1.25 ± 0.01 fetuses/ewe scanned). The proportion of female lambs at marking was 1.5% higher when ewes were fed grain in addition to pasture (53.3%) compared with pasture only (51.8%) although this result was not statistically significant. In Year one of the study, there was evidence that the fatty acid profile of ewe plasma at joining was related to the sex ratio of lambs at marking.

The proportion of female lambs was not consistently higher when ewes were fed grain in addition to pasture compared with pasture only, however, basal diet significantly influenced the sex ratios observed. Further research is required to more accurately predict ewe response to grain feeding.

Executive summary

Previous research at the Wagga Wagga Agricultural Institute conducted by the NSW Department of Primary Industries (DPI) indicated that the proportion of female lambs was approximately 14% higher when ewes were fed oats and cottonseed meal (CSM) compared with silage around joining. A Producer Group, which includes members of the Holbrook Landcare Network (HLN) and the Southern Riverina Sheep Breeders Association, was formed to investigate opportunities to validate at the farm level results from this previous research, which indicated potential economic benefits to sheep producers through manipulation of ewe diets to influence the ratio of male to female lambs.

A series of 11 field trials were conducted in the Holbrook, Wagga and Orange regions of NSW over three years from 2016-2018. On each property, mobs of at least 500 ewes were randomly allocated to one of two treatment groups by alternate selection through a drafting race. Following allocation to treatment, ewes were fed one of two dietary treatments either high in omega-3 (High omega-3, pasture) or high in omega-6 (High omega-6, oats) for four weeks prior to the commencement of joining and for two weeks during a four-eight week natural joining depending on standard practice on each property. Ewes in the high omega-3 group grazed pasture only or were supplemented with silage while ewes in the High omega-6 group were supplemented with approximately 600 g/hd/day of oats or barley in addition to pasture. The sex ratio of lambs was determined at lamb marking.

Results over the three years were variable between properties and between years. Overall, the number of fetuses per ewe at pregnancy scanning was higher across all properties when ewes were fed grain in addition to pasture (1.32 ± 0.01 fetuses/ewe scanned) compared with pasture only (1.25 ± 0.01 fetuses/ewe scanned). The proportion of female lambs was 1.5% higher when ewes were fed grain in addition to pasture (53.3%) compared with pasture only (51.8%), which was not statistically significant. On three properties, the proportion of female lambs was between 4.1-4.8% higher when ewes were fed grain and on two properties the proportion of females was between 4.1-7.2% lower when ewes were fed grain around joining.

The increase in the number of fetuses per ewe at pregnancy scanning when ewes were fed grain was expected given previous research that has examined the relationship between ewe nutrition and fat score and “flushing” and could lead to a significant economic benefit from feeding grain prior to joining. The mean change in sex ratio observed is unlikely to lead to an economic benefit from feeding grain around joining, however, several methodological issues were identified on individual properties that indicated that the actual assessment of sex ratio at lamb marking instead of birth may be problematic and could mask the effect of treatment diet.

In Year one of the study, there was evidence that the fatty acid profile of ewe plasma at joining was related to the sex ratio of lambs at marking. A higher concentration of C18:1n-7 (previously related to a lower overall proportion of the diet as forage compared with grain) was associated with a higher proportion of female lambs. This data suggested that the effect of the basal diet ewes were receiving in addition to the grain treatment was having a significant effect on the sex ratio of lambs.

A preliminary economic analysis was undertaken, whereby the cost of feeding grain was compared with the extra income that could be received for selling ewe lambs for a higher value than wether lambs ($200/hd compared with $110/hd). When the potential income from the sale of lambs was compared with the cost of grain feeding ($6.15/hd feeding oats for 42 days), the nett income from feeding 250 ewes was $2,033 higher when ewes were fed oats in addition to pasture compared with pasture only.

The majority of producers surveyed throughout and at the end of the project suggested they were not convinced to consider changes as a result of the project findings. At current estimated return on investment and given that variability of results in different situations, the financial driver was not strong enough to cause producers to address the perceived barriers. Despite this there was still a high degree of interest in the potential of the practice. If consistency of the outcome on sex ratios of manipulating diet was improved and results could more reliably influence ratios in the desired direction as well as provide an increase in fetuses as observed, most of the producers interviewed would more seriously consider adopting the practice.

There is potential for considerable economic benefit through minor adjustment to current management practices if these results can be consistently translated to the commercial situation. Further work is required in order to determine how to consistently alter the fatty acid profile of ewes leading up to joining and whether this altered profile can consistently lead to a higher proportion of female lambs in extensive grazing situations.

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List of Common Abbreviations

CI = Confidence Interval

CP = Crude Protein

CSM = Cottonseed Meal

HLN = Holbrook Landcare Network

ME = Metabolisable Energy

Omega-3 = Long-chain omega-3 polyunsaturated fatty acid

Omega-6 = Long-chain omega-6 polyunsaturated fatty acid

n-6:n-3 = Ratio of omega-6:omega-3 fatty acids

Fatty Acid Nomenclature

The official name defined by the International Union of Pure and Applied Chemistry (IUPAC) and common names for the major fatty acids discussed in the current report are shown below:

Fatty Acid	IUPAC Proper Name	Common Name	Fatty Acid Group
C18:1n-7	11-Octadecanoic acid (*cis*)	Vaccenic acid	Mono-unsaturated
C18:2n-6	9,12-Octadecadienoic acid (*cis*)	Linoleic acid	Omega-6
C18:3n-3	9,12,15-Octadecatrienoic acid (*cis*)	α-Linolenic	Omega-3

1 Background

Previous work funded by NSW DPI in conjunction with the Graham Centre [Gulliver, 2013 #1527] and MLA [B.LSM.0018 Increasing male lamb proportion by feeding ewes omega-3 fatty acids, \Clayton, 2016 #1787;Clayton, 2016 #1791) indicated that ewes fed a diet high in omega-6 (e.g. grain) pre- and post-joining produce 14% more female lambs than ewes fed a diet high in omega-3 (e.g. silage or pasture). Modelling based on the research results indicates the potential for considerable economic benefit through minor adjustment to current management practices [Robertson, 2016 #2159].

The purpose of the current project was for Holbrook Landcare Network (HLN) to paddock validate the results from the MLA funded project and develop best bet management guidelines. The project also contributed data and knowledge to the ongoing research work to establish intergenerational effects.

2 Project objectives

The objective of the current project was to determine whether results achieved during research trials (achieving greater than 10% more male lambs than females by feeding ewes omega 3 fatty acids at joining), could be replicated in a range of commercial sheep enterprises (years one to three).

2.1 Specific objectives

The specific project objectives were:

By March 2017
Benchmark farmer current practice for feeding ewes at joining and the resultant lamb sex ratio.

By March 2019

1. Determine whether results achieved during research trials (achieving greater than 10% more male lambs than females by feeding ewes omega 3 fatty acids at joining), could be replicated in a range of commercial sheep enterprises by conducting 11 on-farm trials.
2. Investigate the practicality and viability of manipulating ewe diet at joining to influence lamb sex ratios in a commercial sheep enterprise and establish best bet management practices.
3. Establish the impact of feeding a diet high in omega-3 or omega-6 will have on lamb marking percentage.
4. Establish the financial benefit of change in sex ratio and produce best bet feeding guidelines, using producer case studies.

3 Methodology

The project conducted on-farm paddock validation of research into the influence of diet on sex ratio of lambs on 11 sites over three years (five sites in year one, two sites in year two, and four sites in year three). The methodology for each trial site was similar across years and is described below.

3.1 Animals and Dietary Treatments

A minimum of 500 Merino ewes were enrolled into trials at each of 11 sites for Autumn joining (Table 1). Ewes were randomly allocated to one of two treatment groups by alternate selection through a drafting race. Following allocation to treatment, ewes were fed one of two dietary treatments either high in omega-3 (High omega-3, pasture) or high in omega-6 (High omega-6, oats) for four weeks prior to the commencement of joining and for two weeks during a four-eight week natural joining depending on standard practice on each property.

Ewes in the High omega-3 group grazed pasture only or were supplemented with oat/ryegrass silage on one property, while ewes in the High omega-6 group were supplemented with approximately 600 g/hd/day of oats in addition to pasture. Ewes were naturally joined with rams for a standard four-eight week joining period.

Table 1. Details of ewes enrolled into the project over three years.

Year	ID	Property	Breed		n/treatment	Total n	Joining (Weeks)
			Ewe	Ram			
1	1	'Yallock'	Merino	Merino	350	700	4
	2	'Talooby'	Merino	Merino	268	536	5
	3	'Mirridong'	Merino	Merino	563	1126	5
	4	'Coolbaroo'	Merino	White Suffolk	250	500	5
	5	'Maroombah'	Merino	Border Leicester	250	500	6
2	6	'Maroombah'	Merino	Border Leicester	250	500	6
	7	'Yarrawonga'	BL x Merino	White Suffolk	260	520	8
3	8	'Maroombah'	Merino	Border Leicester	250	500	6
	9	'Yarrawonga'	BL x Merino	White Suffolk	260[1]	520	8
	10	'Ardens'	Merino	Merino	255	510	6
	11	'Dalkeith'	Merino	Merino	252	504	6
				Total	3208	6416	

[1]Ewes were fed barley instead of oats.

3.2 Measurements and Observations

At each property, weight and fat score was measured at the commencement of joining. A blood sample was also collected from a representative sample of ewes from each treatment group in all years and analysed for fatty acid profiles in Year one only, according to previously published methods [Clayton, 2012 #1438].

Pasture samples were collected from each paddock on each property prior to the commencement of grain feeding, at the commencement of joining and at the conclusion of joining.

At each property, ewe weight and fat score was determined prior to the commencement of feeding dietary treatments and following joining, and fat score was also determined at the commencement of joining. A 2% allowance was made for empty versus full weights if required and post-joining weights were corrected for fleece weight on one property. Ewe weights were not available at one property post-joining due to wet weather.

Pasture samples were collected from each paddock on each property prior to the commencement of grain feeding, at the commencement of joining and at the conclusion of joining. Pasture yield was assessed using the median quadrat technique [Bell, 2007 #887]. Following collection, a sub-sample of approximately 150 g was dried in an oven at 80˚C for 24 hr for the determination of dry matter (DM) and subsequent analysis of quality. Proximate analyses (% DM) will be determined using near infra-red reflectance (NIR) spectroscopy with a Bruker multi-purpose analyser (MPA, Bruker Optik GmbH, Ettlingen, Germany) and OPUS software (version 5.1) with calibrations developed by the NSW Department of Primary Industries Feed Quality Service (NSW DPI FQS) as described previously [Packer, 2011 #1066]. Total fatty acids were extracted and methylated directly from a separate freeze-dried sample using the one-step procedure of Lepage and Roy [1986\ #264] as modified by Outen et al. [1976\ #324].

Specific details of measurements and sample collections are outlined below.

3.3 Producer Surveys

As part of the project, trial participants and surrounding producers were interviewed to identify what influence this practice could have on commercial sheep enterprises including impacts and barriers to adoption. Interviews were conducted face to face with at least eight trial participants and 20 surrounding producers over the course of the project.

The survey included topics such as: current practices, current measurements recorded, the use of supplementary feeding, interest and application of influencing sex ratio, potential impacts and barriers to adoption and additional information required.

The survey was undertaken both pre and post exposure to the project and its findings to gauge any shift in attitude or behaviour as a result of the project.

4 Results

4.1 Feeding and Joining

All ewes received their treatment diets for the period of time required. Ewes on 10 properties received oats, while ewes on one property in Year three received barley around joining.

4.1.1 Weight and fat score

The average weight and fat score throughout joining for each property is shown in Table 2. On some properties (for example, 'Yallock' in Year one), the weight and fat score of ewes was higher following the consumption of grain in addition to pasture compared with pasture only (Fig. 1). On other properties, however (for example, 'Talooby' in Year one), weight and fat score did not change over the period of feeding (Fig. 2).

Table 2. Average weight and fat score of ewes on each property.

			Weight (kg)		Fat Score	
Year	ID	Property	Pasture	Oats	Pasture	Oats
1	1	Yallock	55.6 (± 0.79)	57.6 (± 0.83)	2.19 (± 0.10)	2.47 (±0.09)
	2	Talooby	48.5 (± 0.63)	48.9 (± 0.81)	1.24 (± 0.04)	1.30 (±0.05)
	3	Mirridong	44.9 (± 0.84)	43.3 (± 0.68)	1.62 (± 0.07)	1.52 (±0.08)
	4	Coolbaroo	54.5 (± 0.89)	53.3 (± 0.82)	2.22 (± 0.12)	2.21 (±0.12)
	5	Maroombah	53.7 (± 1.02)	51.5 (± 1.12)	1.98 (± 0.10)	2.04 (±0.10)
2	6	Maroombah	58.8 (± 3.09)	58.0 (± 1.68)	2.15 (± 0.15)	2.35 (±0.12)
	7	Yarrawonga	64.2 (± 2.35)	65.8 (± 2.83)	1.98 (± 0.26)	2.04 (±0.17)
3	8	Maroombah	50.5 (± 0.80)	51.9 (± 0.79)	1.50 (± 0.07)	1.58 (±0.07)
	9	Yarrawonga	63.7 (± 1.92)	64.8 (± 1.65)	3.18 (± 0.26)	3.45 (±0.17)
	10	Ardens	49.1 (± 0.60)	50.7 (± 1.75)	1.55 (± 0.04)	1.46 (±0.12)
	11	Dalkeith	53.0 (± 1.17)	50.4 (± 1.36)	1.47 (± 0.12)	1.50 (±0.09)

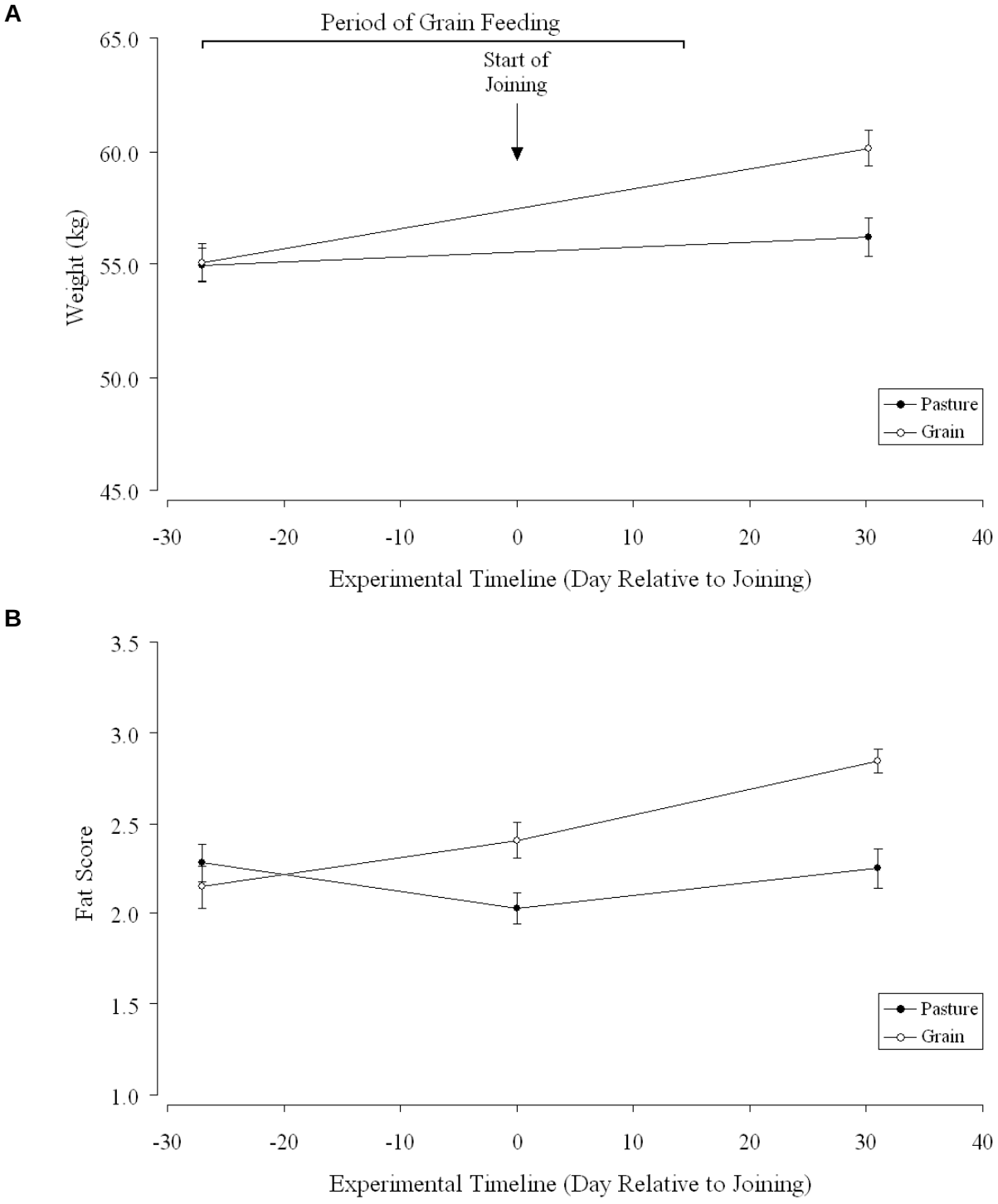


Fig. 1 Ewe weight (A) and fat score (B) prior to the commencement of feeding grain and following feeding and joining at property 1 'Yallock'.

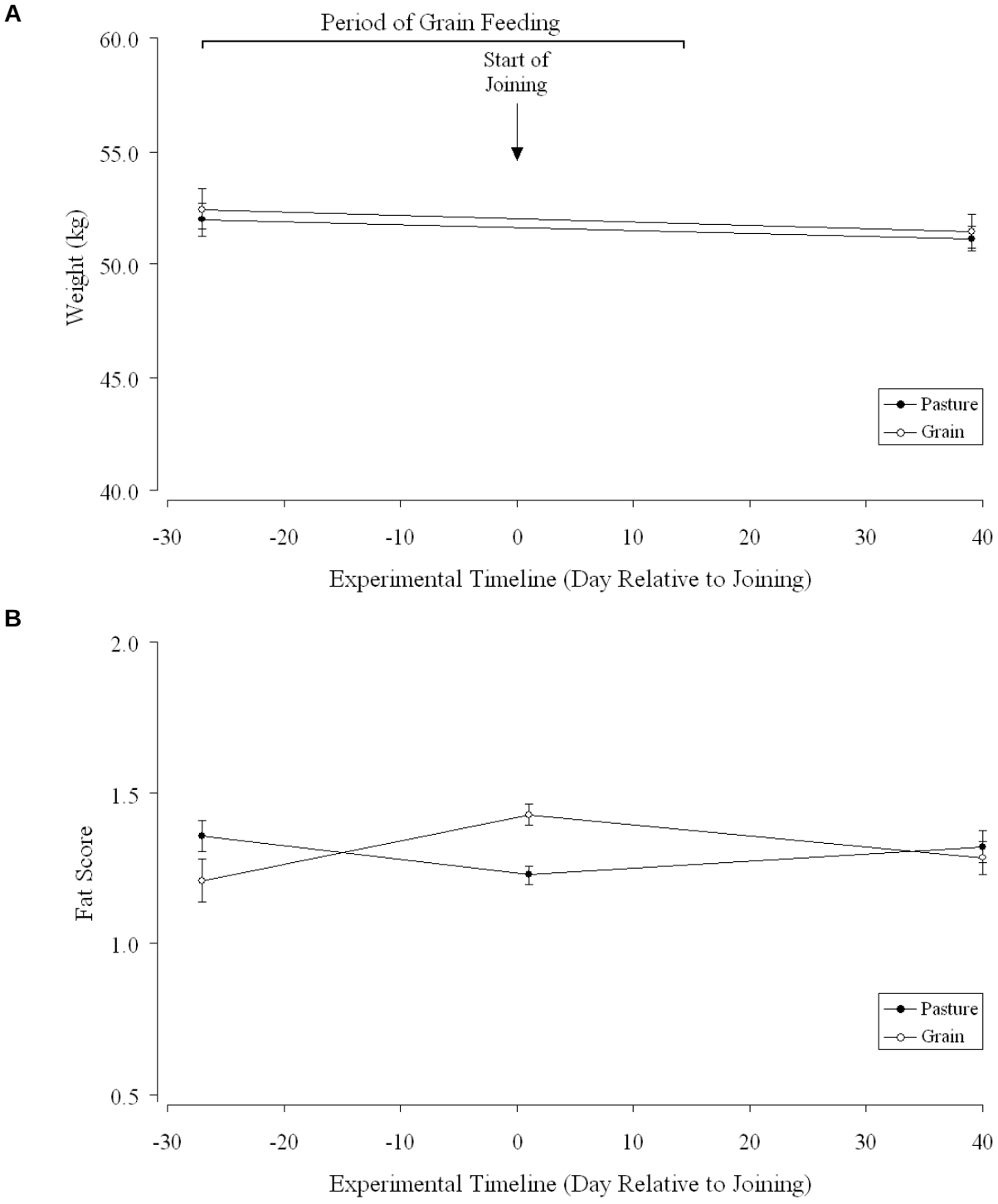


Fig. 2 Ewe weight (A) and fat score (B) prior to the commencement of feeding grain and following feeding and joining at property 2 'Talooby'.

4.1.2 Pasture samples

The average energy, protein and fat content of pasture samples (or silage on one property) are presented in Table 3 and values for the grain fed on each property are presented in Table 4. Although the proximate analyses of the pasture samples was similar between treatment groups on most properties, the basal diet of pasture appeared to influence the outcomes of the study, which will be discussed in detail later.

Table 3. Energy, protein and fat content of pasture samples across all years of the project.

			CP (% DM)		Fat (% DM)		ME (MJ/kg DM)	
Year	ID	Property	Pasture	Grain	Pasture	Grain	Pasture	Grain
1	1	Yallock	12.4	10.4	2.1	2.7	7.1	6.9
	2	Talooby	7.0	11.9	1.4	1.7	6.1	7.1
	3	Mirridong*	9.5	9.5	2.9	2.9	9.2	9.2
	4	Coolbaroo	11.5	9.7	2.1	1.1	7.7	7.7
	5	Maroombah	7.1	6.6	1.6	1.7	6.2	6.4
2	6	Maroombah	5.4	6.8	1.2	1.5	6.3	7.1
	7	Yarrawonga	10.0	12.6	1.6	1.4	10.3	9.1
3	8	Maroombah	7.3	7.9	1.7	2.5	6.6	7.2
	9	Yarrawonga	12.6	7.0	2.0	1.1	9.1	6.1
	10	Ardens	5.0	5.9	1.0	1.0	7.0	8.7
	11	Dalkeith	6.9	7.1	1.6	1.1	8.6	7.3

*Results are shown for oats/ryegrass silage.

Table 4. Energy, protein and fat content of grain fed to properties across all years of the project.

Year	ID	Property	CP (% DM)	Fat (% DM)	ME (MJ/kg DM)
1	1	Yallock	13.7	4.1	12.2
	2	Talooby	8.4	5.8	12.2
	3	Mirridong	15.1	5.4	12.3
	4	Coolbaroo	13.6	6.0	12.5
	5	Maroombah	9.2	6.3	12.2
2	6	Maroombah	8.8	5.8	11.8
	7	Yarrawonga	12.8	5.8	12.7
3	8	Maroombah	8.2	5.5	11.9
	9	Yarrawonga[1]	12.3	1.7	12.6
	10	Ardens	7.2	5.2	11.9
	11	Dalkeith	10.8	5.5	12.3

[1]All grain was oats except property 9 (Yarrawonga, Year 3) which was barley.

Pasture Fatty Acids

The ratio of n-6:n-3 fatty acids (ratio of C18:2n-6, linoleic acid to C18:3n-3 α-linolenic acid) in pasture and grain was estimated for samples collected in Year one of the project (Table 5). The ratio of n-6:n-3 varied from 0.41 to 1.00 within property and was as high as 1.52 on 'Yallock' when ewes were allocated to the oats treatment group.

Table 5. Ratio of n-6:n-3 in pasture samples for Year one.

	Pasture								Oats
	Ewes Fed Pasture			Ewes Fed Oats			Mean		Grain
Property	1	2	3	1	2	3	Pasture	Oats	
Yallock	0.41	1.00	0.84	1.34	1.00	1.52	0.75	1.28	25.18
Talooby	0.83	2.71	-	1.32	1.40	-	1.77	1.36	26.15
Mirridong[1]	0.97	0.41	0.29	2.14	0.41	-	0.56	1.27	27.38
Collbaroo	0.48	0.99	1.09	0.48	1.06	0.94	0.85	0.82	31.61
Maroombah	0.54	0.54	1.57	0.44	1.25	1.03	0.88	0.91	37.15

n-6:n-3 ratio is the ratio of C18:2n-6, linoleic acid to C18:3n-3 α-linolenic acid.
[1]Pasture or silage.

4.2 Reproduction Rate

4.2.1 Pregnancy scanning

The proportion of ewes scanned pregnant did not differ by more than 3.3% between treatment groups on any property (Table 6).

Table 6. Proportion of ewes pregnant.

			Pregnant (%)		
Year	ID	Property	Pasture	Grain	Difference
1	1	Yallock	89.8 (± 1.6)	91.5 (± 1.5)	2.8
	2	Talooby	85.2 (± 2.2)	86.9 (± 2.1)	1.8
	3	Mirridong	96.4 (± 0.8)	97.7 (± 0.6)	2.3
	4	Coolbaroo	88.5 (± 2.0)	85.9 (± 2.2)	-3.3
	5	Maroombah	95.4 (± 1.4)	94.2 (± 1.5)	-1.2
2	6	Maroombah	96.4 (± 1.7)	94.0 (± 1.7)	-2.4
3	8	Maroombah	86.7 (± 1.7)	89.9 (± 1.7)	3.2
	9	Yarrawonga	96.9 (± 1.7)	96.5 (± 1.7)	-0.4
	10	Ardens	87.4 (± 1.7)	88.9 (± 1.7)	1.6
	11	Dalkeith	88.0 (± 1.7)	89.6 (± 1.7)	1.4
		Overall	91.7	92.6	0.9

The number of fetuses per ewe scanned was increased by more than 5% on six out of 10 properties (Table 7) when ewes were fed grain in addition to pasture compared with pasture only. The number of fetuses per ewe scanned was lower when ewes were fed oats compared with pasture at joining on one property ('Coolbaroo'). This corresponded with a lack of difference in liveweight or fat score when ewes were fed oats compared with pasture on that property.

Table 7. Number of fetuses per ewe.

		Fetuses per Ewe Pregnant		Fetuses per Ewe Scanned		
ID	Property	Pasture	Grain	Pasture	Grain	Difference
1	Yallock	1.58 (± 0.03)	1.68 (± 0.03)	1.42 (± 0.03)	1.55 (± 0.03)	**0.13 (9.2%)**
2	Talooby	1.32 (± 0.03)	1.35 (± 0.03)	1.13 (± 0.04)	1.17 (± 0.04)	0.04 (3.9%)
3	Mirridong	1.28 (± 0.02)	1.35 (± 0.02)	1.24 (± 0.02)	1.34 (± 0.02)	**0.10 (8.2%)**
4	Coolbaroo	1.66 (± 0.04)	1.63 (± 0.04)	1.47 (± 0.04)	1.40 (± 0.04)	-0.08 (-5.5%)
5	Maroombah	1.36 (± 0.03)	1.51 (± 0.03)	1.30 (± 0.04)	1.43 (± 0.04)	**0.13 (10.3%)**
6	Maroombah	1.31 (± 0.03)	1.43 (± 0.03)	1.26 (± 0.04)	1.35 (± 0.04)	**0.09 (7.0%)**
8	Maroombah	1.34 (± 0.03)	1.37 (± 0.03)	1.17 (± 0.04)	1.23 (± 0.04)	**0.06 (5.5%)**
9	Yarrawonga	1.44 (± 0.03)	1.48 (± 0.03)	1.39 (± 0.04)	1.43 (± 0.04)	0.04 (2.8%)
10	Ardens	1.10 (± 0.03)	1.32 (± 0.03)	0.96 (± 0.04)	1.17 (± 0.04)	**0.21 (21.3%)**
11	Dalkeith	1.28 (± 0.03)	1.29 (± 0.03)	1.13 (± 0.04)	1.16 (± 0.04)	0.03 (2.8%)
	Overall	1.36 (± 0.01)	1.44 (± 0.01)	1.25 (± 0.01)	1.32 (± 0.01)	0.08 (6.4%)

When results from all trials were combined (Fig. 3), the number of fetuses per ewe scanned was higher when ewes were fed grain in addition to pasture compared with pasture only (1.33 vs 1.25 fetuses/ewe scanned, difference = 7.6 fetuses/ewe or 6.4% more fetuses).

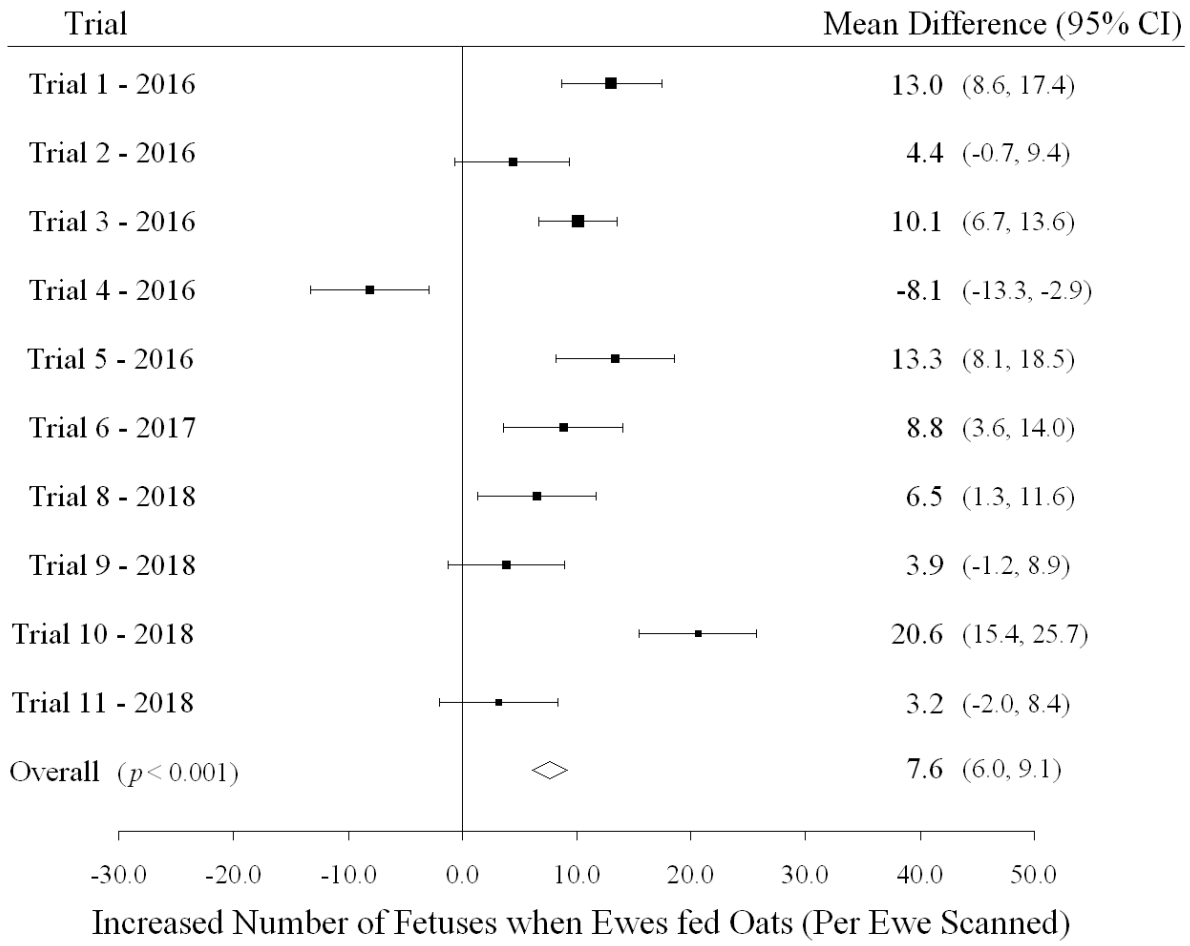


Fig. 3 Increase in the number of fetuses per ewe scanned when ewes were fed oats in addition to pasture compared with pasture only (values are Mean increase in number of fetuses/ewe, ± 95% CI). The size of the square for individual trials indicates the relative contribution to the overall result.

The magnitude of the difference between treatment groups can be estimated using an Effect Size. The effect size is calculated from the difference between treatment means divided by the pooled standard deviation. The increased number of fetuses when ewes were fed grain in addition to pasture compared with pasture only showed an overall Effect Size of 0.11, which is considered a Small Effect [Fig. 4 \Faul, 2007 #272].

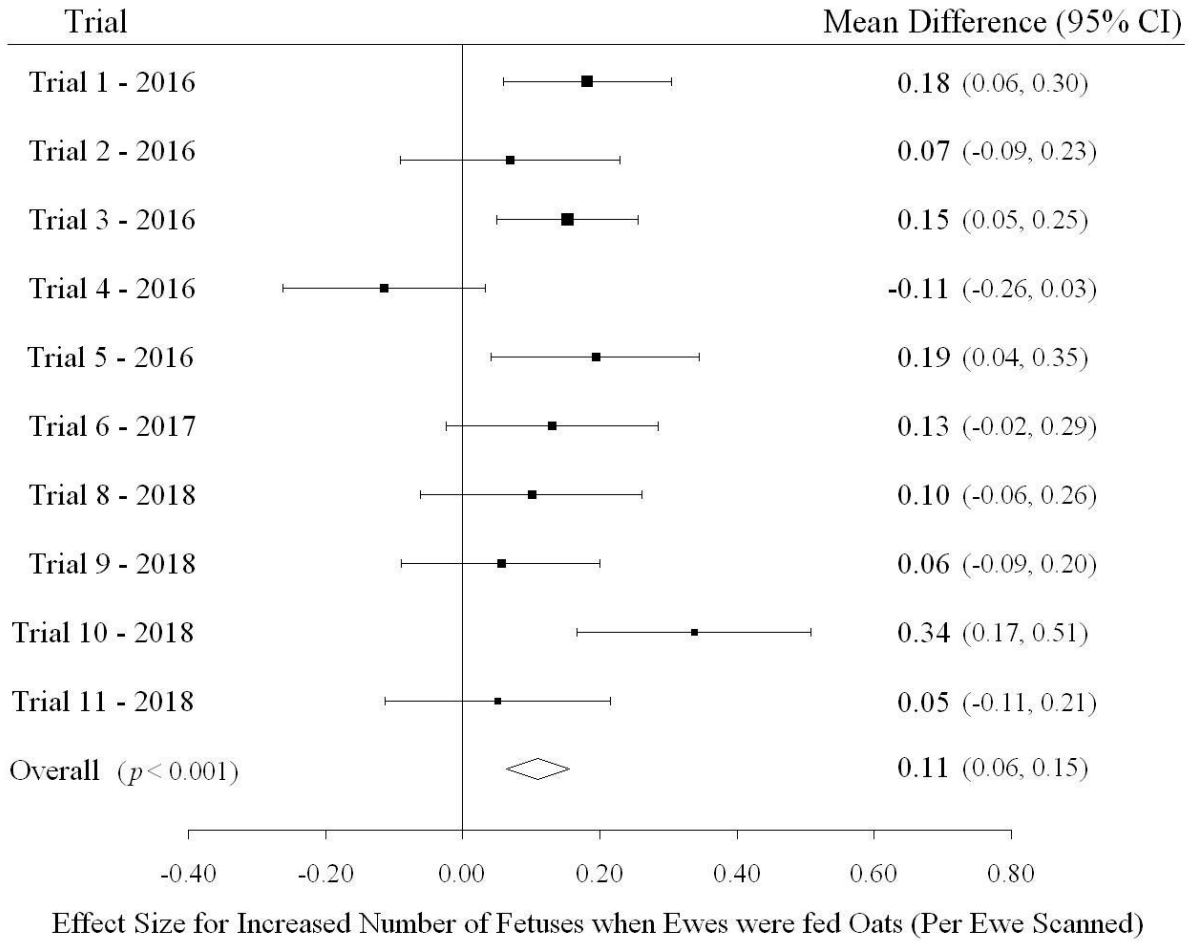


Fig. 4 Effect Size for the increased number of fetuses per ewe scanned when ewes were supplementary fed oats in addition to pasture compared with pasture only (values are Effect Size ± 95% CI). The size of the square for individual trials indicates the relative contribution to the overall result.

4.2.2 Lamb marking

The number of lambs marked per ewe joined was increased by more than 5% on seven out of eleven properties (Table 7) when ewes were fed grain compared with pasture only. The number of lambs marked was not changed or lower on 3 properties ('Talooby', 'Mirridong' and 'Coolbaroo'). This corresponded with a large loss of fetuses on two out of those three properties (see below). The overall lamb marking rate (per ewe joined) would have been statistically higher ($p < 0.001$) when ewes were fed grain in addition to pasture compared with pasture only, however, it is not possible to interpret a statistical analysis of the data due to the lack of replication within property (see further discussion below).

Table 8. Lamb marking rate when ewes were fed grain in addition to pasture compared with pasture only.

		Lamb Marking Rate (%)				
		Ewes at Marking		Ewes Joined		
ID	Property	Pasture	Grain	Pasture	Grain	Difference
1	'Yallock'	99.1	106.9	95.1	106.6	**11.4 (12.0%)**
2	'Talooby'	84.8	86.0	81.3	80.2	-1.1 (-1.4%)
3	'Mirridong'	78.3	79.1	77.4	78.2	0.7 (0.9%)
4	'Coolbaroo'	104.8	92.2	96.0	85.6	-10.4 (-10.8%)
5	'Maroombah'	87.3	101.8	82.8	91.2	**8.4 (10.1%)**
6	'Maroombah'	100.4	107.4	97.2	104.8	**7.6 (7.8%)**
7	'Yarrawonga'	125.3	136.7	123.8	134.6	**10.8 (8.7%)**
8	'Maroombah'	61.3	78.4	58.8	75.6	**16.8 (28.6%)**
9	'Yarrawonga'	100.4	118.8	97.3	109.2	**11.9 (12.3%)**
10	'Ardens'	53.9	62.0	51.8	59.6	**7.8 (15.2%)**
11	'Dalkeith'	60.1	64.3	57.9	60.7	2.8 (4.8%)
	Total	86.5	92.6	83.4	89.2	5.8 (6.8%)

4.2.3 Loss of Ewes

There were a number of ewes missing between joining and lamb marking (Table 3). It is not clear whether the loss of ewes was due to ewe deaths or if ewes were missing due to other factors such as mis-mustering or mixing of ewes due to fencing. It was not possible to individually assess ewes at each operation on each property, nor was it possible to ensure that fencing was adequate for mob separations on all properties.

Table 9. Loss of ewes.

			Loss of Ewes (%)[1]		
Year	ID	Property	Pasture	Grain	Total
1	1	'Yallock'	4.0	0.3	2.1
	2	'Talooby'	4.1	6.7	5.4
	3	'Mirridong'	1.1	1.2	1.2
	4	'Coolbaroo'	8.4	7.2	7.8
	5	'Maroombah'	5.2	10.4	7.8
2	6	'Maroombah'	3.2	2.4	2.8
	7	'Yarrawonga'	1.2	1.5	1.3
3	8	'Maroombah'	4.0	3.6	3.8
	9	'Yarrawonga'	3.1	2.3	2.7
	10	'Ardens'	3.9	3.9	3.9
	11	'Dalkeith'	3.6	5.6	4.6
		Overall	3.5	3.7	3.6

[1]It is not clear whether these figures are ewe deaths or missing ewes due to mis-mustering or poor fencing.

4.2.4 Fetal Loss

There was also a significant loss of fetuses/lambs between scanning and marking (Table 10). On average, 35.8% of fetuses identified at scanning were not present at marking, with no difference between treatment groups. Again, it is not clear whether these losses are attributable entirely to lamb deaths, or whether ewe and lamb losses from mis-mustering of mixing between paddocks due to poor fencing contributed to the loss. In Year three, in particular, some lamb losses were attributed to drought conditions and having to supplementary feed grain to ewes and lambs (see comments below regarding assessment of methodological issues).

Table 10. Loss of fetuses from scanning to marking when ewes were fed oats in addition to pasture or pasture only around joining.

			Fetal Loss (%)			
Year	ID	Property	Pasture	Grain	Total	Difference
1	1	'Yallock'	31.5	31.3	31.4	-0.2
	2	'Talooby'	26.4	29.3	27.8	2.9
	3	'Mirridong'	37.4	43.6	40.6	6.2
	4	'Coolbaroo'	35.1	38.3	36.7	3.2
	5	'Maroombah'	35.1	35.8	35.5	0.7
2	6	'Maroombah'	21.9	21.6	21.7	-0.3
3	8	'Maroombah'	49.1	38.0	43.4	-11.1
	9	'Yarrawonga'	29.5	23.0	26.2	-6.5
	10	'Ardens'	45.9	48.8	47.5	2.9
	11	'Dalkeith'	48.2	47.2	47.7	-1.0
		Overall	35.5	36.0	35.8	1.5

4.3 Sex Ratio

4.3.1 Overall results

The proportion of female lambs was higher on seven out of eleven properties when ewes were fed oats in addition to pasture compared with pasture only, however, the overall change in sex ratio was small (Table 11). The proportion of female lambs was more than 4% lower on two properties when ewes were fed oats compared with pasture only. Overall, the difference in the sex ratio of lambs between treatment groups was not significant (Fig. 5).

Table 11. Lamb sex ratio when ewes were fed grain in addition to pasture or pasture only at joining.

			% Females		
Year	ID	Property	Pasture	Grain	Change
1	1	'Yallock'	53.8	53.1	-0.7
	2	'Talooby'	49.1	51.6	**2.5**
	3	'Mirridong'	49.5	54.3	**4.8**
	4	'Coolbaroo'	51.3	47.2	-4.1
	5	'Maroombah'	53.5	54.8	**1.3**
2	6	'Maroombah'	49.9	54.0	**4.1**
	7	'Yarrawonga'	50.0	54.6	**4.6**
3	8	'Maroombah'	62.6	55.4	-7.2
	9	'Yarrawonga'	51.3	52.1	**0.8**
	10	'Ardens'	57.1	56.8	-0.2
	11	'Dalkeith'	47.8	50.7	**2.9**
		Total	51.8	53.3	**1.5**

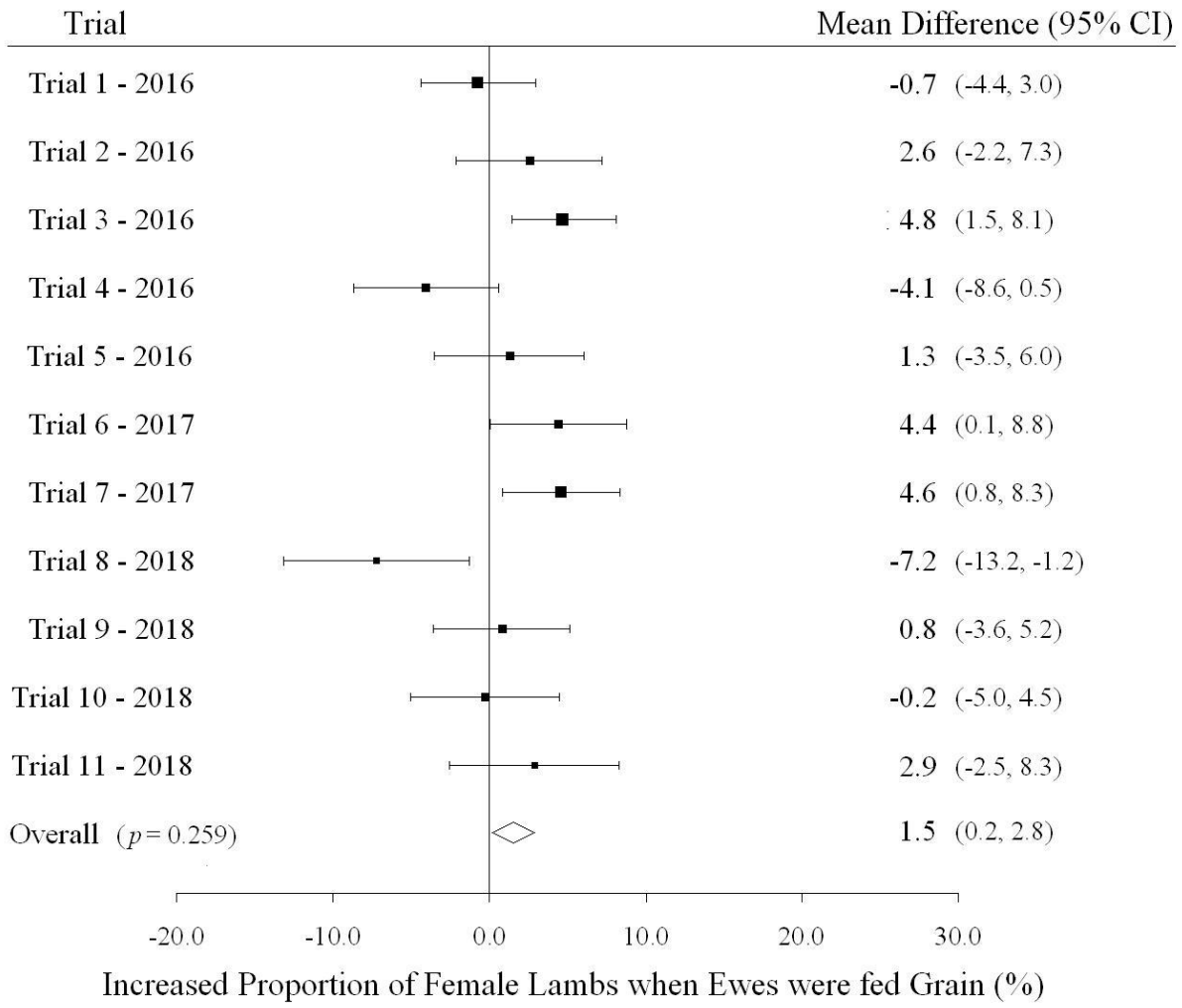


Fig. 5 Increased proportion of female lambs (%) when ewes were fed grain in addition to pasture compared with pasture only (values are Mean % increase in proportion of female lambs, ± 95% CI). The size of the square for individual trials indicates the relative contribution to the overall result. The grain type in all trials was oats except for Trial 9 which was barley.

4.3.2 Relationship with fatty acids

The proportion of female lambs was not consistently higher when ewes were fed oats in addition to pasture compared with pasture alone across five field trials in Year one. Blood samples were collected from a sub-set of ewes in each treatment group on each property (after feeding experimental diets at the time of ram introduction) and the fatty acid profile of these samples was determined.

Plasma indices associated with higher pasture intake were negatively related to the proportion of female lambs (Fig. 6). That is, if there was an indication that the diet was lower in fresh pasture (relatively higher in grain) as indicated by the concentration of 11-octadecanoic acid (C18:1n-7, vaccenic acid), then the proportion of female lambs was higher.

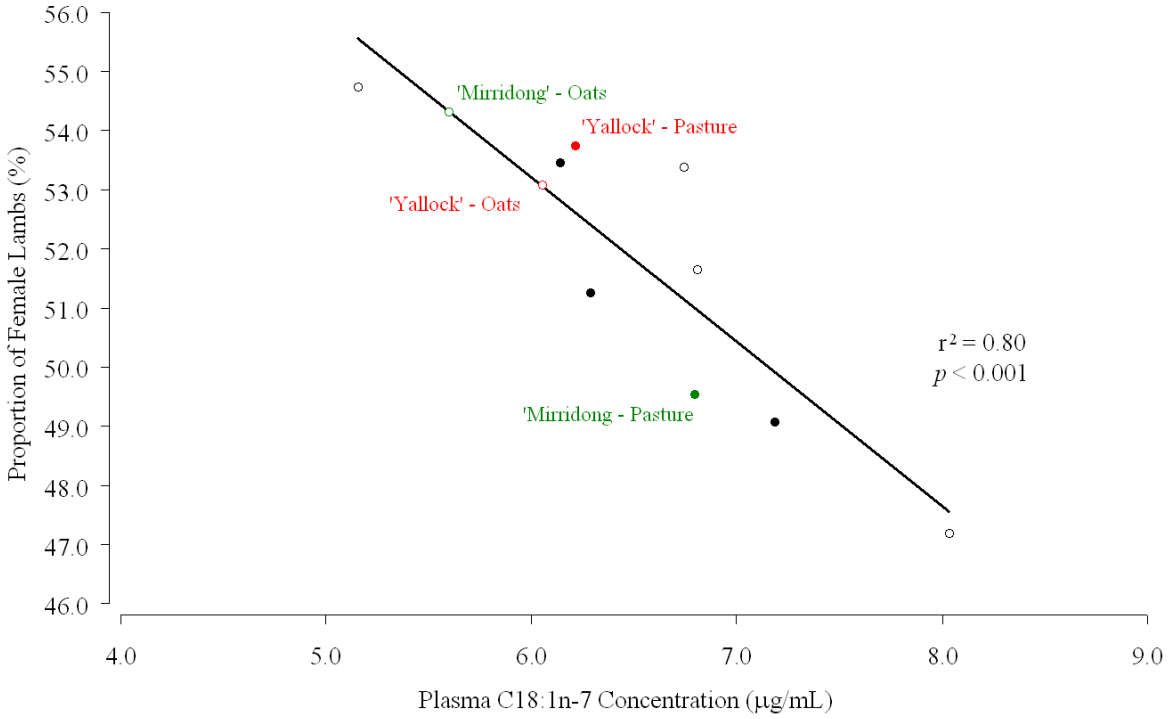


Fig. 6 Negative correlation between plasma C18:1n-7 concentration and the proportion of female lambs across property when ewes were fed oats in addition to pasture (○), or pasture only (●) in Year one of the study.

The variability in sex ratio across all trials in Year one was around 10%, which was similar to the objective of the project: "Determine whether results achieved during research trials (**achieving greater than 10% more male lambs than females** by feeding ewes omega 3 fatty acids at joining), could be replicated in a range of commercial sheep enterprises". These results highlight the difficulty of consistently altering the fatty acid profile of ewes on individual properties. For example, on one property ('Yallock'), the sex ratio was not different between treatment groups, however, the concentration of C18:1n-7 fatty acid was also not different between the two groups (Fig. 6). Alternatively, on another property ("Mirridong"), a lower concentration of C18:1n-7 was observed when ewes were fed oats in addition to pasture/silage compared with pasture/silage only (indicating that a higher proportion of the whole diet consisted of oats), which was associated with a higher proportion of female lambs.

4.4 Economic Analysis

A preliminary economic analysis was conducted for a property in Year one of the study. The main purpose was to examine the potential nett financial benefit from altering the lamb marking rate or the sex ratio of lambs towards females in a self-replacing Merino flock or a Border Leicester x Merino first cross ewe breeding enterprise.

4.4.1 Assumptions used in the economic analysis

No. Ewes fed	= 250
Feed Costs	= $6.15/hd (feeding for 42 days @ $280/t)
Lamb Sales:	Wethers = $110/hd; Ewes = $200/hd
Lamb Marking	= 90.9% (Omega-6 oats group) vs 82.8% (Omega-3 pasture group)
Sex Ratio	= 54.8% (Omega-6 oats group) vs 53.5% (Omega-3 pasture group)
	= 1.3% difference between groups

4.4.2 Potential nett income

When the potential income from the sale of lambs was compared with the cost of grain feeding, the nett income from feeding 250 ewes was $2,033 higher when ewes were fed oats in addition to pasture compared with pasture only (Table 12).

Table 12. Potential nett income from the sale of lambs compared with cost of grain feeding.

	Sale of Lambs			
Sales ($)	Pasture	Oats	Difference	
Ewe lambs	22,200	25,000		
Wether lambs	10,560	11,330		
Total	32,760	36,330	3,570	
- Cost of Grain			1,538	
Nett Income			2,033	($8.13/hd)

This Nett income does not take into account additional costs associated with feeding the grain, such as diesel or labour, however, it also does not take into account other potential benefits from increasing the number of female lambs, such as improved selection pressure and genetic gain that could be achieved.

4.4.3 Sensitivity analysis and break-even

A summary of potential benefits of increasing either the proportion of female lambs or the total number of lambs marked, given the cost of feeding, is shown below:

Table 13. Sensitivity analysis for the change in potential nett income ($/hd of ewes joined) with changes in lamb marking percentage and sex ratio of lambs following grain feeding at joining.

Change in	Change in Marking %			
Female %	0	5	10	15
0	-6.15	2.09	9.89	18.13
5	-2.19	6.05	13.85	22.45
10	1.41	10.01	18.17	26.77
15	5.01	13.97	22.13	31.09

- For every 1% increase in female lambs marked (with no difference in marking % between groups);
  - results in an extra $0.72/hd of ewes joined .
  - Therefore, the break-even point to cover the cost of grain = 8.5% more females.
- For every 1% increase in marking (no difference in the proportion of females between groups);
  - results in an extra $1.53/hd of ewes joined.
  - Therefore, the break-even to cover the cost of grain = 3.8% higher marking.
- For every 1% increase in marking **AND** females combined;
  - results in an extra $2.42/hd of ewes joined.
  - Therefore, the break-even to cover the cost of grain = 2.6% increase in both.

4.5 Producer Surveys

4.5.1 Pre Project Survey

The following is a summary of responses collected from participating producers surrounding producers interviewed about their current practices and their awareness and response to the practices being examined through this project. Where response differed significantly between the two groups they have been identified, otherwise responses are amalgamated.

Overview

- Producers surveyed manage between 300-3500ha. Participants farms were between 1350-3000ha.
- Just over half of enterprises incorporated some cropping with the remainder only grazing. Some incorporated cattle but sheep was their major enterprise.
- All respondents described their sheep enterprise as either growing or stable.
- They run between 600 and 13,000 merino and cross bred ewes and joining times were between four-twelve weeks (majority five-six) between Nov and Mar. All participants joined in Feb-Mar for five-six weeks.

Common practices

- All producers currently undertake drenching, all except two undertake ewe booster vaccinations, all except one vaccinate at lamb marking, and all except one undertake lamb booster vaccinations. The same landholder was the exception to all three practices.
- 75% undertake ewe classing and ram checks to some degree either by wool class or checking for physical faults. All except three undertake pregnancy scanning and one of those indicated they were moving towards it, and all except two undertook conditions scoring of ewes.
- Just over half are mulesing

Data records

- All except one producer records marking %.
- Despite most reporting undertaking condition scoring, less than 1/3 of producers record the results.
- Those pregnancy scanning had records of the results.
- Most were recording weaning % results (all participants) and 2/3 were recording at least a best estimate of lambing %.
- Less than 25% of producers surveyed recorded lambs sex ratio information however most indicated they made the observation at marking time. Several made comments about historically having close to 50/50 ratio or having a slight female bias.

At joining

- All except two producers reported using supplementary feed at joining although two more reported ‘only if we need to’. Those who don’t supplementary feed relied on a mix of native pastures and fodder crops.
- Supplementary feed used varied widely but included barley, triticale, oats, lupins and some hay and silage.

Awareness and value of the research

- More than half of the respondents were aware of the research prior to the interview process however few really understood in much detail.
- All except one producer indicated that they could identify situations where they might use the strategy. The most common responses were around ewe breeding:
    - strategically targeting replacement ewes,
    - increase ewe turnover (cut ideally would need more than 10%)
    - accelerate herd growth
    - more ewes brings more flexibility to their system, especially good first cross ewes
- Of those who thought they could identify situation where it would be useful, some were cautious about reliability of the outcome and the influence of standing feed base.
- One participant said after undertaking the process it was quite complicated to achieve. They were still positive but cautious about risk vs reward.
- The landholder who could not see the usefulness was also a participant. They said they can't see the economic benefit, suspect the base feeding negates the impact in 'real' situations and argued the logistics of managing separately would outweigh the gains.
- Two of the producers who had stud flocks said they might also use it to target rams. Both of the studs said they probably wouldn't bother in their commercial flock. One because they joined in Nov and usually has plenty of standing feed on offer, the other because they felt targeting maximum lambs was more important than sex ratios in the commercial flock.
- Three mentioned they could see benefit in producing more male lambs from terminal sires.

Impact on Business

- Almost half of responders said it could have a significant impact (rating 4-5) on their business, if it was implementable. The most common reason was the potential to provide selection pressure on ewes to accelerate herd improvement and growth. Also with price trend at the moment ewes are becoming far more valuable than wethers.
- One producer said it wouldn't impact their business much because they were already doing it to some extent. The majority said it could have some impact but were uncertain of the value proposition given the changes they might have to make to feeding systems.

Barriers to adoption

- There were several potential barriers identified.
    - Producers though the availability of green feed would be an issue if they wanted to try and target male lambs. Having green feed or silage at joining time can be expensive depending on seasons.
    - This was due to quality green feed or silage being more valued for lamb finishing at that time of year than for this purpose. Several growers questioned whether the $ would stack up.
    - There were less barriers identified for grain feeding for females however if the feed supplement needed to be oats there were some concerns by two Holbrook based producers as they had found them hard to get in the past. There was generally no issue with grain feeding of some description.

- Early break or late summer rain was a concern for grain feeding as green growth dilutes effect of grain diet.
- Additional labour required to delivering a specific diet was a concern, although if the economic returns stacked up it would be negated.

Information required before you might make a decision on this practice

- Comments can be summarised into three themes.
  - Feed types. Would need to know exactly what feed gets the best result ie. wheat, triticale, oats? And what the best protocol for that feed is. How much is enough Omega 6 in feed? Can we get that in other ways?
  - Economics of change. Would need the economic data on what it cost to change feeding system v's potential returns to be made.
  - Confidence in change. Would need to be able to confidently quantify change. Before producers would be inclined to change they want to see consistent % change demonstrated in a commercial situation. Partly a lack of data about what the ratio is under their current practice. Lots of effort required to trial it individually so really need to have it demonstrated consistently elsewhere. Do we have data from NZ/HRZ areas where they don't feed grain? Are they consistently producing more male lambs than female?

4.5.2 Post Project Survey

Are the results of the project different than you expected?

- Most respondents noted that results were as they had expected from the project
- two responded that they expected a more clear result towards influencing sex ratios
- one respondent was surprised by the increase in scanning results in the grain feeding groups

What is the key point you would take away from the project findings?

- Most responses were about the more general positive impacts of grain feeding on scanning % and on lamb survival rather than anything specific to lamb sex ratios
- Several responses indicated that there was a low degree of confidence in effecting lamb ratios at all or questioned the financial reward for doing so

Given the results of the project would you consider any changes to your current joining practices?

- Only one respondent suggested they would alter ewe feeding to influence sex ratios in future but two others also indicated they make changes to influence an increase in fetuses
- The majority suggested they would not consider changes as a result of the project and as reasons cited:
  - Other farming system factors carrying more importance
  - Current grain feeding was producing good results
  - Seasonal influences driving feeding strategies (drought, feed availability)

Through being involved/aware of the project have you changed any practices with regards to the information you collect about your flock during joining and lambing?

- Half of the respondents indicated they were satisfied with the information they collect and the understanding of their flocks at joining and lambing
- The other half responded that they were more aware of survival rates and sex ratios than they were previously but didn't indicate any changes they would make as a result

Is there any further work in this area of research that you could see adding value to your sheep enterprise in the future, or would like more information on?

- There were several responses that saw value in continued research into practical ways to increase female lamb numbers. This was a common theme that there was value in the potential outcome but lower degree of confidence in the current process
- There was also equal support for more information on increasing lamb survival
- Several other areas of interest were identified as potentially adding value to the enterprises of participants:
    - Exploring the value of establishing more pastures v's supplementary feeding
    - Potential for genetic mapping to determine if ewes are more likely to have either female or male lambs
    - Feed ration ratio – what proteins may be a better option

4.6 Producer Field Days

Two producer field days were held to provide results from the research projects to both trial participants and other interested producers in the area. One field day was held in the Holbrook area, where the majority of participants were located in Year one and the other field day was held in Euchareena (near Orange) where a number of field sites were located in Years two and three of the project.

4.6.1 Holbrook field day

The first field day was held in Holbrook on Friday 24/08/2018. The field day was attended by 12 producers, including some that had participated in the producer demonstration trials.

We received encouraging feedback from the event and discussed a number of things people wanted to know, such as the economic viability of feeding. Of particular interest was the possible intergenerational effects of the diets and people were keen to see more data be collected regarding that, even though they understood the difficulties in doing so.

4.6.2 Euchareena field day

The second field day was held in Euchareena on Thursday 31/01/2019. It was intended that the field day would be held in November/December of 2018 to coincide with the collation of results from Year three of the project, however, a number of LLS Drought Workshops were held in the area around that time, so the Sex Ratio field day was postponed until early 2019.

A total of 23 producers attended the field day in Euchareena. A number of LLS and DPI staff members attended as well.

We received good feedback from the event and a number of producers (who had not participated in the current project) indicated that they were feeding grain leading up to joining as they thought this lead to a higher proportion of female lambs on their property and they had been doing this for a "few" years now.

Another producer also mentioned that they had observed that the basal diet fed to ewes appeared to influence the sex ratio of lambs on their property. The producer indicated that they have been recording the sex ratio at lamb marking for a number of years and "some paddocks were consistently different from others". This highlights the need to more accurately quantify the effect of basal diet in future studies.

A number of producers were also disappointed with the fetal loss observed across all studies and the potential ramifications this has on the ability to interpret the data from the trials. Support was given for some more controlled studies whereby lambs could be assessed at birth. They understood the limitations of this approach and knew that it would be dependent on the availability of funding.

A common theme from producer feedback was that people were very interested in being able to manipulate the sex ratio but there were reservations about how easy and repeatable it would be to get beneficial results. If changes in sex ratio could be predicted more accurately, then there were few barriers to adoption, as people thought the benefits would outweigh any costs. A lot of producers indicated that if they could see some more positive results where others had successfully implemented the feeding to change sex ratio, then they would probably follow.

4.6.3 Summary of producer feedback and research questions raised

There were a number of benefits of conducting the on-farm trials in addition to the actual results obtained. It was important to be able to discuss the project with producers to find out what information they needed in order to be able to successfully implement the feeding strategies on-farm. A number of important future research questions were identified, including:

- What type of grain can be fed? A lot of producers were already feeding barley or triticale to ewes and wanted to know if they fed at the correct time prior to joining if this would have an effect.
- How can we predict when feeding is needed given the basal diet available to ewes leading up to joining? Basal diet and individual paddocks appear to be influencing sex ratio, so it will be important to know when feeding is required in addition to basal diet.
- How much grain is required and will this vary with the type of grain fed? For example, if oats is higher in fat/omega-6 than barley, will less oats be required to gain the same effect?
- What are the intergenerational effects of feeding on-farm? How can we best monitor future generations for reproductive potential and effects on sex ratio?
- How can we more accurately monitor the number of lambs born? Is any kind of remote sensing available to assist?

4.7 Extension and Adoption Pathways

Two producer field days were held and summaries of the research results and case studies have been produced. These will be distributed through the HLN and incorporated into information packages to be available to all producers in the district. A number of presentations to producers and research groups were also given (see below).

4.7.1 Presentations incorporating results from the project

A number of presentations were given incorporating the results from the project:

- Presentation to the Sheepmeat Council International Delegation, Graham Centre, 8th August, 2016
- Australian Association of Ruminant Nutrition Workshop, Melbourne, 6th April, 2017
- Blayney Pre-Sowing Information Session, Central Tablelands LLS, Blayney, 30th January 2019
- Livestock Field Day - Turning Pastures into Profits, Sheep Connect, ANFD Site, 4th April 2019

5 Discussion

5.1 Study Outcomes

The primary outcomes of the study, to conduct 11 field trials examining the effect of grain feeding at joining on the sex ratio of lambs over 3 years were achieved. Results of fatty acid analyses undertaken in Year 1 of the project indicate that the basal diet consumed by each of the treatment groups on each property (ie. pasture) had a significant effect on the outcome of the study, ie. the sex ratio of lambs. The results of the study will be discussed in terms of individual effects and possible implications on-farm.

5.1.1 Pregnancy scanning rate

The major finding of the trials was that the number of fetuses per ewe was higher when ewes were fed grain in addition to pasture compared with pasture only around joining. The mean effect across all trials was 7.6% more fetuses when ewes were fed grain. This result could have been related to a higher fat score or condition score of ewes following the consumption of grain, however, it is not clear whether this was the case in the current project. This higher pregnancy scanning rate could be expected to translate into a higher number of lambs at marking or weaning. Attention should focus on lamb survival and ensuring that this higher pregnancy scanning rate translates to lambs alive at weaning and sale.

5.1.2 Sex ratio

The proportion of female lambs was 1.5% higher when ewes were fed oats in addition to pasture compared with pasture only around joining, although this result was not statistically significant. Results of fatty acid analyses undertaken in Year 1 of the project indicate that the basal diet consumed by each of the treatment groups on each property (ie. Pasture) had a significant effect on the outcome of the study, ie. the sex ratio of lambs. Overall, there was a 10% variation in the proportion of female lambs across properties and treatment groups in the first year of the project and a 15.4% variation across all properties over the 3 years of the project. Further research is required in order to determine the causes of these variations, particularly with basal diet.

5.1.3 On-farm implications

A combination of a higher pregnancy scanning rate and higher proportion of female lambs could translate to an increased nett income on-farm. Using observed data from Year one of the study, the nett income from feeding oats around joining (per head of ewes joined) could be $8.13 higher compared with feeding pasture only. Other benefits may occur from feeding that are not as easily measured, such as intergenerational effects that producers would like to be able to quantify.

5.1.4 Barriers to adoption

Producers indicated that if the success of feeding to manipulate sex ratio could be predicted more accurately and consistently, then there would be few barriers to adoption. A number of producers feed grain at different times and could see the potential benefits from feeding leading up to joining. Feeding grain to ewes prior to joining was thought to be achievable to most producers and there was flexibility in being able to feed using different methods, including trail feeding, or using troughs or self-feeders. Grain prices and the economics of feeding were important considerations and a definitive answer as to how profitable feeding would be will not be known until more details of feeding can be determined, such as how to predict the response in addition to basal diet.

5.2 Methodological Considerations

5.2.1 Effect of basal diet

Results of fatty acid analyses undertaken in Year one of the project indicate that the basal diet consumed by each of the treatment groups on each property (ie. Pasture) had a significant effect on the outcome of the study, ie. the sex ratio of lambs.

An example of how the basal diet appeared to be influencing the sex ratio can be seen on three properties. Firstly, at ‘Yallock’, the proportion of female lambs was not different when ewes were fed oats (53.1% females) compared with pasture only (53.8% females), however, the fatty acid profile of the blood of ewes was also not different at the time of joining (Figure 1 – Red Circles). Secondly, at ‘Coolbaroo’, the proportion of females was actually lower when ewes were fed oats prior to joining (47.2%) compared with pasture only (51.3%), however, the fatty acid profile analysis showed that the fatty acids previously associated with higher total forage intake and a lower proportion of females, were consistent with the overall relationship observed across properties (Figure 1, Blue circles). Finally, at ‘Mirridong’, the proportion of females was higher when ewes were fed oats (54.3%) compared with pasture (silage, 49.5%), which agreed with the analysed concentration of fatty acids shown in previous analyses (Figure 1, Green Circles).

As there was only one paddock per treatment group (ie. there was no replication within property), when ewes were fed grain in a particular paddock, the main question remains "what would have happened if the ewes in that particular paddock were **not fed grain** at that particular time?" This means that although a particular proportion of female lambs was observed when ewes were not fed grain, because those ewes were in a separate paddock and the basal diet appeared to influence the result, the outcome of that group may not have been indicative of a true Control group. Therefore, a number of suggestions for possible improvements to the methodology for future studies are outlined below.

1. Within property, split a single paddock into four with temporary fencing. Therefore, there would be two blocks (replicates) per treatment with grain feeding occurring on top of a similar basal diet.

2. Within property, rotate ewes from each treatment group between paddocks. This would need to occur at least twice per week and may not be able to be undertaken easily (as discussed in an email to Andrew Thompson prior to the commencement of trials in Year two of the project).

3. Within property, have three paddocks per treatment group. The total number of sheep could still be 250 per treatment, although 300 per treatment (100 per paddock) would be better.

4. Within each property, assess the number of lambs at birth. This would be very difficult (not to mention expensive) in a commercial environment and would probably only be able to be undertaken at a research facility.

Future studies should attempt to undertake at least some of these changes. There may need to be a stronger link between controlled pen feeding studies and the extensive on-farm trials that were undertaken in order to find out some more information, including the effect of basal diet, what type of grain to feed and how long to feed.

5.2.2 Assessment of lambs at marking

The difficulty in assessing lamb sex ratio at marking compared with birth is highlighted in the results from at least two properties in Year three, as the lamb marking rate was different when ewes were fed oats compared with pasture. For example, at 'Maroombah', the proportion of female lambs was higher when ewes were fed pasture only (62.6%), compared with oats (55.4%). However, lamb survival and the lamb marking rate was lower when ewes were fed pasture (61.2%) compared with oats (78.5%). In comparison, the pregnancy scanning results were not as different between groups, which indicates there was a significant loss of lambs between scanning and marking in the pasture group that did not necessarily occur in the oats group. It is well known that male lambs have a lower survival rate than female lambs under times of stress (Bangar et al., 2016), which could be expected given drought conditions and hand-feeding of ewes and lambs. If this was the case, it may be possible that when ewes were fed pasture only at 'Maroombah', more male lambs died (resulting in a lower overall lamb marking %), which resulted in a higher **proportion** of females surviving. It is also possible that a similar situation occurred at 'Yarrawonga' and 'Dalkeith' and results should therefore be treated with caution.

By the same reasoning, data for a higher proportion of female lambs at 'Mirridong' in Year one of the study could also be subject to error due to lamb losses. Although the lamb marking rate was

similar when ewes were fed oats in addition to pasture/silage (76.5%) compared with pasture/silage only (78.3%), there was a greater loss of fetuses when ewes were fed oats which could have skewed the result. The proportion of female lambs was higher when ewes were fed oats in addition to pasture/silage (54.3%) compared with pasture/silage only (49.5%), however, the loss of fetuses from scanning to marking was also 6.2% higher when ewes were fed oats (43.6%) compared with pasture/silage (37.4%). Therefore, it is possible that the higher loss of fetuses when ewes were fed oats was attributable to a loss of male lambs, therefore, skewing the result towards females. This highlights that it appears critical to be able to determine the sex of lambs actually born, rather than only those that survive to marking.

In terms of research design, methodology and study quality, it is probably important to keep in mind that over the whole project 35.8% of all data was missing prior to analysis and assessment of the effect of treatment diets.

5.2.3 Statistical analysis of lamb marking percentage

It is not possible to determine the actual effect of diet on lamb marking percentages with the final design that was implemented on-farm. While we always expected to monitor lamb marking % and try to examine whether any differences could be accounted for across properties, scientifically this cannot be determined. This is primarily due to the fact that there is no replication of treatments within property and no ability to control the environment at lambing, as the ewes lambed in different paddocks. The average values reported are only observations and are dependant on a number of factors outside of the control of the study (and the effect of treatment), for example, predation and exposure.

The results for pregnancy scanning are less likely to be affected by between paddock variation within property and, as such, more weight could be given to the results, particularly with replication between properties. However, there is still a lot of variation in the results between properties which makes statistical analysis difficult and there are still factors outside the control of the study that can affect pregnancy scanning results, such as ram effects and paddock effects.

In addition to the limitations of assessing the number of lambs at marking between different paddocks, statistical analysis is still difficult, as it is not possible to determine how many dry ewes there were, as well as how many singles, twins or triplets were born.

6 Conclusions/recommendations

6.1 Effect of diet on lamb sex ratio on-farm

Feeding grain to ewes for four weeks prior to joining and for the first two weeks of joining could lead to a 1.5% increase in the proportion of female lambs and a 7.6% increase in the number of fetuses at pregnancy scanning. Further research is required in order to determine the effect of basal diet on sex ratio and how to more accurately manipulate ewe fatty acid status with supplementary feeding in addition to the basal diet.

Feedback from producers indicated there was strong interest in being able to increase the proportion of high value female lambs, especially in times of drought and during flock number re-building. The cumulative effects of altering the sex ratio, increasing the number of fetuses/lambs and potential intergenerational effects were all seen as important ways that farm productivity and profitability could be increased.

6.2 'Best-Bet' Feeding Guidelines

Feeding ewes 600 g/hd/day oats for four weeks leading up to joining and for the first two weeks of joining may lead to a higher proportion of female lambs by up to 1.5%. Further increases in the proportion of female lambs may be able to be achieved under certain feeding conditions. These guidelines are premised on being able to ensure that ewes consume the oats and the basal diet is such that a significant change in the proportion of omega-6:omega-3 fatty acids is achieved.

Feeding ewes oats for around joining as specified above may lead to 7.6% more fetuses at pregnancy scanning compared with ewes grazing pasture only. This higher pregnancy scanning rate could lead to a higher return from the sale of lambs if lamb survival can be maintained until weaning and sale.

The basal diet of ewes could also affect the sex ratio of lambs and should be considered when undertaking feeding. For example, to increase the proportion of female lambs then producers should consider ensuring that the basal diet does not contain green feed with omega-3. Conversely, if producers would like to increase the proportion of male lambs, it is possible that the incorporation of more green feed into the basal diet will be beneficial.

6.3 Practicality of manipulating diet at joining and barriers to adoption

Producers indicated that whilst they could see it was possible to manipulate ewe diet prior to and at joining, the majority would be unlikely to pursue the practice at this stage.

Responses indicated that there were stronger drivers influencing diet than the potential effect on sex ratios. These included:

- seasonal drivers such as opportunistic feed on offer and grain availability
- established drought feeding strategies
- feeding for condition and general increase in fetuses

The greatest barriers to adoption were identified as:

- the availability of green feed to target more male lambs
- the prioritisation of quality green feed or silage for more valued lamb finishing
- access to oats or appropriate grain at the right price
- early break or late summer rain was a concern for grain feeding as green growth dilutes effect of grain diet
- additional labour required to delivering a specific diet

None of these barriers were seen to be insurmountable if the return on investment was sufficient.

At current estimated return on investment and given that variability of results in different situations, the financial driver is not strong enough to cause producers to address the perceived barriers. Despite this there is still a high degree of interest in the potential of the practice. If consistency of the outcome on sex ratios of manipulating diet was improved and results could reliably influence ratios in the desired direction as well as provide an increase in fetuses as observed, most of the producers interviewed would more seriously consider adopting the practice.

6.4 Future research

A number of research questions were identified by producers during the current project, including:

- What type of grain can be fed?
- How to categorise basal diet and how to best incorporate supplementary feeding in addition?
- How much grain is required and will this vary with the type of grain fed?
- What are the intergenerational effects of feeding on-farm?
- How can we more accurately monitor the number of lambs born?

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8 Appendix