Final report

Adding sustainability traits to the MLA resource flock

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Abstract

To select more efficient and more sustainable sheep, breeding tools that consider feed intake and methane production against associated productivity traits (e.g. growth and body composition) are warranted. In this project feed intake, methane production, growth and body composition were measured on MLA Resource Flock lambs at Katanning (L.GEN.1814) to help inform and develop new genetic tools that consider feed-intake and methane efficiency in sheepmeat production.

Genotyped lambs from the MLA Resource Flock at Katanning born in 2022 and 2023 (n=1830) were measured for methane and body composition at early post weaning age (total=1830) and measured for feed intake (n=736), methane (n=1300) and body composition (n=1575) a second time prior to slaughter. Notably, over 75% of variation in daily feed intake of lambs was explained by weight and growth, with methane production and body composition, as measured in this project, contributing minimally. This underscores the central role of weight and growth in driving feed efficiency, under *ad libitum* finishing systems. Importantly, sires across all major breed types exhibit extremes in residual feed efficiency, suggesting broad genetic variability that can be leveraged for selection.

While preliminary findings are promising, expanding the dataset with additional measurements will solidify confidence in these conclusions and enhance the reliability of breeding values. Additionally, industry investment in the extension of breeding tools and services to producers, ensuring that producers understand and adopt new breeding tools that consider feed intake efficiency and methane production will enable the industry to translate research findings into tangible economic and environmental benefits, fostering sustainable progress in Australian red meat production.

Executive summary

Background

Efficient use of feed is a critical determinant of productivity and sustainability in livestock systems. Understanding factors that influence feed intake and efficiency is essential to develop strategies that enhance growth performance, reduce costs, and mitigate environmental footprints, particularly methane emissions, associated with livestock production.

This study measured the dynamics of feed intake and methane production traits in sheep under *ad libitum* feed conditions. By analysing feed intake, growth characteristics, methane production, and genetic variability, this research aims to provide preliminary data to Sheep Genetics for the development of breeding values and tools to assist producers in selecting for genetic improvement on this group of traits. Ultimately, the findings contribute to the broader goal of enhancing efficiency and sustainability in the red meat industry.

Objectives

The direct output of the project will be the data required to make quantitative estimates of genetic parameters for feed intake (RFI and FCE) in sheep including, heritability estimates, genetic correlations and ASBVs. These data will be made available to Sheep Genetics for calculation of genetic parameters that will then be made available to the sheep industry. Comparisons will also be made between feed intake and body composition to determine the differences between sheep that have low or high feed efficiency with the portion of data within phase One and again with later phases. This includes the following measurements on up to 1,500 lambs from the 2020 and 2021, 2022 & 2023 MLA Resource Flock (L.GEN.1814):

i. Feed intake

ii. Growth

iii. Gas production (including CO2 and methane)

iv. Body composition

As well as submission of data to MLA via Sheep Genetics for the routine analysis and where relevant development of residual feed intake, feed conversion efficiency, methane production Australian Sheep Breeding Values (ASBV).

Methodology

Lambs from the MLA resource flock at Katanning, born in 2022 and 2023 (totalling 1,830 lambs), were assessed for methane emissions, body composition, and feed intake. Methane emissions were measured twice using Portable Accumulation Chambers (PACs): first at early post-weaning and again prior to slaughter for specific kill groups. The lambs were fed supplements of grower pellets and hay in 2022 and a 70% oat:30% lupin mix in 2023, with methane recorded under controlled conditions. Body composition was assessed twice using ultrasound at the C-site to measure muscle and fat. Feed intake was measured over 28-32 days for about half of each kill group (n=758 lambs), with data cleaned to exclude anomalies and summarized into daily intake for each sheep.

Kill groups 2-4 from both cohorts entered indoor feedlot facilities before slaughter, with lambs stratified by weight and randomized by sire into pens. Methane and feed intake data collection followed strict protocols, including removing records with nonlinear methane accumulation or

unstable feed intake traits. In total, the study provides a robust dataset on methane production, feed efficiency, and body composition under standardized conditions for lambs across two cohorts.

Results/key findings

- Average daily intake trait becomes stable in 15 days.
- Including part-record intake data improved the estimate of the average daily intake trait for weight and growth.
- A majority (>75%) of daily feed intake variation under *ad libitum* indoor feedlot conditions was attributable to weight and growth, while methane production and body composition had minimal additional influence.
- Sires across all major breed types can exhibit extremes in residual feed efficiency for weight and growth.
- Methane output is largely driven by roughage intake thus selecting for greater feed-use efficiency is likely to also reduce methane production.
- A total of 1,828 genotyped lambs were phenotyped for methane production, growth, and, in some cases, feed intake, alongside their core economic traits (weight, growth, conformation, disease resistance, and carcass quality). This comprehensive data collection significantly enhances sheep genetics research and development.

Benefits to industry

This project provides significant progress in understanding feed intake efficiency and methane production in sheep, with over 250 sires used across key breeds and 1,830 measurements taken in total across traits. The findings support that variation in daily feed intake is mostly attributable to weight and growth. Importantly, methane output is strongly linked to roughage intake, and integrating feed intake measurements with methane production offers a powerful dataset to develop breeding values and other genetic tools.

The development of robust facilities and protocols achieved by this project marks a pivotal step forward, and maintaining momentum in this research will empower the red meat industry to meet future production targets while reducing environmental impact.

Future research and recommendations

Future research should focus on further validating the reduced intake measurement period to ensure consistent and accurate estimation of feed intake traits across diverse conditions and genetically varied populations. While preliminary findings are promising, expanding the dataset with additional measurements will solidify confidence in these conclusions and enhance the reliability of breeding values and tools.

Industry investment in the extension of breeding tools and services to producers, ensuring that sheep producers understand and adopt new breeding objectives that incorporate feed intake efficiency and methane production. This will enable the industry to translate research findings into tangible economic and environmental benefits, fostering sustainable progress in sheep finishing systems.

Table of contents

1. Background

Efficient use of feed is a critical determinant of productivity and sustainability in livestock systems. As global demand for animal protein increases, improving feed efficiency while minimising environmental impacts has become a key focus. Understanding factors that influence feed intake and efficiency is essential to develop strategies that enhance growth performance, reduce costs, and mitigate environmental footprints, particularly methane emissions, associated with livestock production.

In sheep production, feed intake and production efficiency are influenced by a complex interplay of genetic, physiological, and environmental factors. Key traits such as growth rate, body composition, and methane emissions are often interlinked, presenting both opportunities and challenges for optimising performance. Accurate estimation of feed intake and efficiency traits is essential for identifying superior animals and refining management practices (Kock 1963; Korver 1988; Pryce et al. 2014; Vandehaar et al. 2016; Gurgeira et al. 2022). However, the duration of intake measurement and the inclusion of ancillary data—such as weight and growth traits—can affect significantly the reliability and practicality of such estimations (Macleay et al 2014; Paganoni et. al. 2017; Paganoni et al. 2024).

This study investigates the dynamics of feed intake and efficiency traits in sheep under *ad libitum* finishing systems. By analysing feed intake, growth characteristics, methane production, and genetic variability, this research aims to provide insights that support genetic improvement and potentially management interventions. To select more efficient and more sustainable sheep, breeding tools that consider feed intake and methane production against associated productivity traits (e.g. growth and body composition) are warranted. In this project feed intake, methane production, growth and body composition were measured on more than 700 lambs (2022-born & 2023-born) from the MLA Resource Flock at Katanning (L.GEN.1814) to assist in the development of genetic tools that can assist producers to achieve genetic progress in more efficient and sustainable sheep production. Ultimately, the findings contribute to the broader goal of enhancing efficiency and sustainability in the red meat industry.

2. Objectives

The direct output of the project will be the data required to make quantitative estimates of genetic parameters for feed intake (RFI and FCE) in sheep including, heritability estimates, genetic correlations and ASBVs. These data will be made available to Sheep Genetics for calculation of genetic parameters that will then be made available to the sheep industry. Comparisons will also be made between feed intake and body composition to determine the differences between sheep that have low or high feed efficiency with the portion of data within phase One and again with later phases. This includes the following measurements on up to 1,500 lambs from the 2020 and 2021, 2022 & 2023 MLA Resource Flock (L.GEN.1814)

i. Feed intake (achieved, n=736)

ii. Growth (achieved, n=1830)

iii. Gas production (achieved, n=1300)

iv. Body composition (achieved n=1575)

As well as submission of data to MLA via Sheep Genetics for the routine analysis and where relevant development of residual feed intake, feed conversion efficiency, methane production Australian Sheep Breeding Values (ASBV).

This project has successfully delivered on its key objective to provide measures of feed intake, growth, methane production and body composition under *ad libitum* feedlot conditions from a minimum of 700 genotyped MLA resource flock lambs.

These measures have been submitted to Sheep Genetics to make quantitative estimates of genetic parameters for feed intake (and residual feed intake) in sheep including, heritability estimates, genetic correlations and Australian Sheep Breeding Values. This data will be made available to the sheep industry via Sheep Genetics.

3. Methodology

3.1 Abbreviations

ADG = Average Daily Gain (kg/hd/day)
AEC = Animal Ethics Committee
ADI = Average Daily Intake (kg of dry matter/head/day)
DM = Dry Matter
DEXA = Dual Energy X-Ray Absorption
DPIRD = Department of Primary Industries and Regional Development Western Australia
DROP = Birth year of the lamb cohort
DORP = Dorper dam breed
MMT = Merino/Maternal dam breeds
MMWT = Mean Metabolic Mid Weight (kg)
NDF = Neutral Detergent Fibre (% roughage content in feed)
ME = Metabolisable Energy
PAC = Portable Accumulation Chamber
VPI = Voluntary Potential Intake (kg of dry matter/head/day)

3.2 Animals

Lambs from the MLA Resource Flock at Katanning born in July 2022 (n=929) and July 2023 (n=899) were measured for methane and body composition at early post weaning age (total=1830) and measured for feed intake (total=736), then methane (n=1300) and body composition (n=1575) a second time prior to slaughter. After weaning in approximately September each year (2022 and 2023) the lambs were stratified by sire and weight into four kill groups of approximately 230 (Table 1).

Table 1. Kill group numbers and dates for the 2022-born and 2023-born cohorts of lambs from the MLA Resource Flock at Katanning

Kill Group	2022-born			2023-born		
	No.	Kill Date	Breed	No.	Kill Date	Breed
Kill Group 1	224	20-Feb-23	Dorper	198	15-Jan-24	Merino/Maternal/ Terminal/Dorper
Kill Group 2	231	20-Mar-23	Merino/Maternal/ Terminal/Dorper	240	12-Feb-24	Merino/Maternal/ Terminal
Kill Group 3	231	25-Apr-23	Merino/Maternal/ Terminal/Dorper	204	9-Apr-24	Dorper
Kill Group 4	243	18-May-23	Merino/Maternal/ Terminal/Dorper	241	14-May-24	Merino/Maternal/ Terminal
Total	929 (survived to slaughter)			883 (survived to slaughter)		

Kill groups 2,3 and 4 of both cohorts entered the feed intake facility consecutively between Jan-May prior to slaughter. In each kill group, approximately half (10 of 20 pens) had average daily feed intake captured for approximately 3-4 weeks prior to slaughter (Figure 1, Table 2).

Table 2. Kill group numbers measured for methane at post-weaning age ($CH4^1$) and pre-slaughter ($CH4^2$), for feed intake and body composition pre-slaughter from the 2022 and 2023-born lambs from the MLA Resource Flock at Katanning.

	2022-born				2023-born			
	$CH4^1$	$CH4^2$	Intake	BodyComp	$CH4^1$	$CH4^2$	Intake	BodyComp
Kill Group 1	224	0	0	198	214	0	0	
Kill Group 2	231	230	130	230	231	234	129	231
Kill Group 3	231	230	123	231	213	176	112	211
Kill Group 4	243	239	126	234	241	191	116	240
Total	**929**	**699**	**379**	**893**	**899**	**601**	**357**	**682**

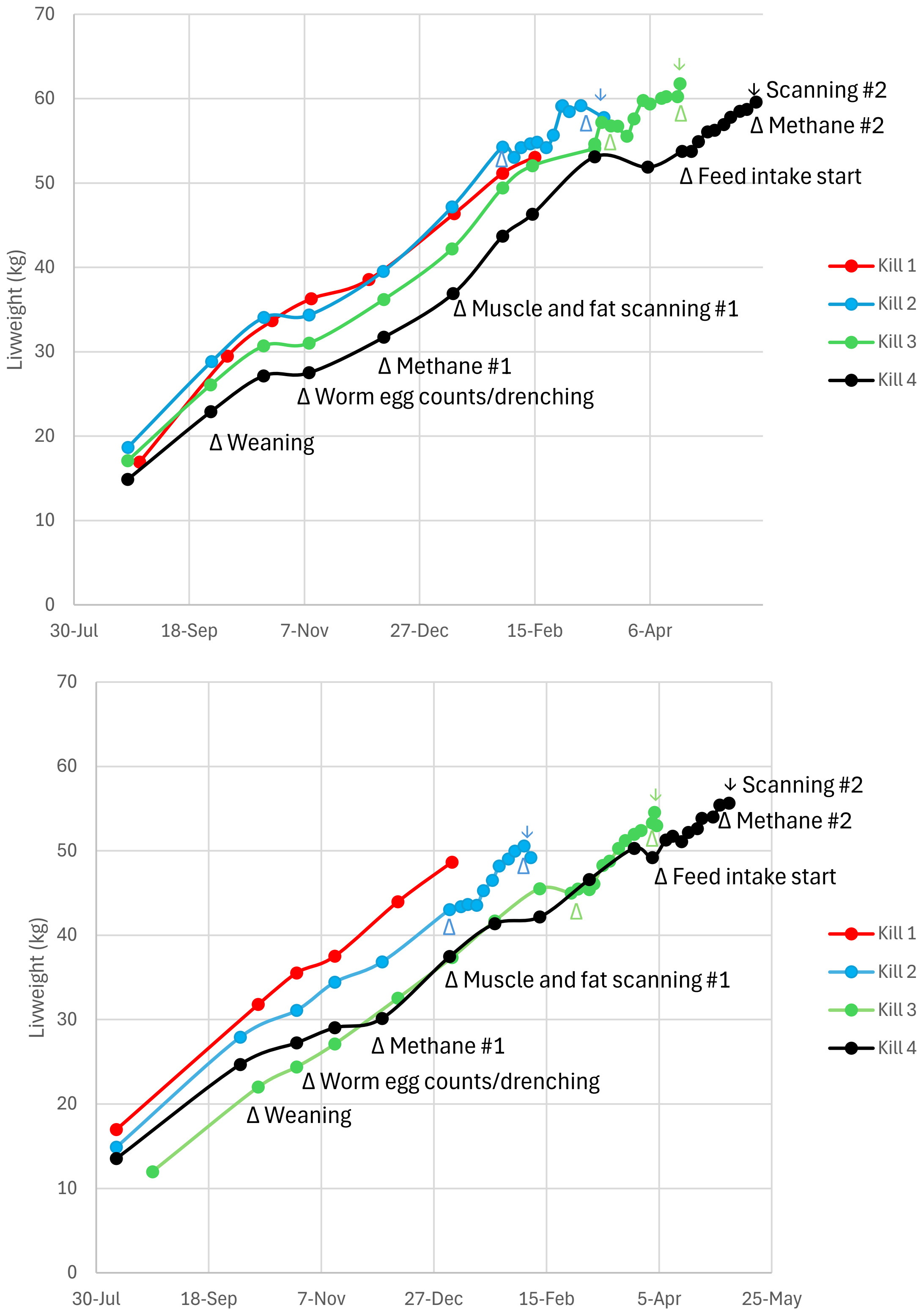


Figure 1. Average liveweight profiles from marking to slaughter for four kill groups of lambs from the MLA Resource Flock born in July 2022 (upper) and July 2023 (lower). The last month prior to slaughter for kill groups 2-4 represents the period inside the feed intake shed where liveweights are measured twice weekly.

3.2.1 Body composition

Muscle and fat was measured twice via ultrasound at the C-site (Robinson et al. 1992) using LAMBPLAN accredited scanner Stocksmart (#13013) for all sheep. They were first measured at early post-weaning age (Jan 2022 and Jan 2023) and again immediately prior to slaughter (Figure 1). Change in fat and muscle were calculated by subtracting the post-weaning measurement from the pre-slaughter measurement.

Live DEXA scans were completed on the 2022-born cohort in prone position in January and March 2023 (n=253). Human, rather than live animal settings were used to capture the images which increased the risk of inaccurate scans due to imprecision in spinal placement. Additionally an inadequate sedation protocol rendered the first scans unviable due to interference from the animal restraints. New standard operating procedures for light sedation and DEXA scanning were developed and approved by the DPIRD AEC early in 2024, not in sufficient time for further scanning approvals for this project.

Completed scans (n=253) are viable for sub region fat estimates, recently a majority of full images (n=236) have been manually re-drawn to exclude buckle interference and these images will be processed using correction algorithms (Hunter, 2011). Lean, bone and fat data recovered will be submitted to Sheep Genetics with a summary and associated methods intended for inclusion/publication in a short paper for the AAAS conference in 2026 adding valuable information for phenotypic and future genetic correlations and breeding value estimates post the delivery of this project.

3.2.2 Growth

Lamb growth rates were calculated over three periods between weaning and slaughter. The first growth rate was calculated for the period when the first methane measurement was recorded in December (for both cohorts) and included the two post-weaning weights taken either side of the methane measurement (approximately 2 months, including 3 weights).
The second growth rate was calculated for the entire period from weaning until slaughter (approximately 9 months, including 20 weights).
The third growth rate was calculated for the period the lambs were in the feed intake shed where liveweights were recorded twice weekly (approximately 1 month, including 10 weights). The third growth rate was the growth rate relevant to the calculation of their residual feed intake.

3.2.3 Feed intake

All lambs prior to entry into the feed intake shed were adapted to an *ad libitum* pellet diet over 14 days (Table 3). The sheep were then stratified by weight (to reduce bullying) and randomised by sire into up to 20 pens with 10-14 sheep per pen. Chutes leading into the feeders were kept open (wide) for three days to allow the sheep to adjust to the pens and feed units. Following this three day ‘training’ period, the lead-in chutes to the feed units were narrowed to restrict feeder access to one sheep at a time and data collection commenced.

Due to limitations with EID readers, the maximum number of pens capturing data at the same time is restricted to 10 pens. Therefore, intake measurements were recorded for half of each kill group in the facility. The other half of the kill group underwent the same treatments but without individual intake being recorded.

A small number (~1%) of sheep were moved to the hospital pen in each group due to shy feeding resulting in weight loss and/or scouring which was rectified by supplementing their pellet diet with chaff.

Table 3. Nutritional testing of pellets fed to progeny throughout methane and feed intake testing.

	2022 Pellets	2023 Pellets
Dry matter (%)	91.6	91.5
Moisture (%)	8.4	8.5
Crude Protein	13.1	13.2
Acid detergent fibre (%)	18.7	24.6
Neutral detergent fibre (%)	34.5	45.9
Digestibility of dry matter (%)	72.1	62.4
Digestibility of organic dry matter (%)	71.4	62.1
Metabolisable energy (MJ)	11.9	10.6
Fat (%)	4.5	4.4
Ash (%)	5.8	5.1

Feed intake data processing

Feed Intake data is captured as individual meals across the feed intake measurement period. Each group resided in the feed intake facility for approximately 30 days prior to slaughter. A cleaning algorithm is used to remove meals that have;

- Blank EID
- Feed Intake is 0 or negative
- EID does not belong to sheep recorded in the facility (false tag or tag associated with human management activity)
- Outlier meals (3 SD from mean meal intake)

A standard operating procedure (Appendix 8.3) for adaptation and management of lambs undertaking a feed intake test was developed and approved by the DPIRD AEC. Together with feeding algorithms and their descriptive functions has been shared with the project P.PSH.2011 - Selecting for more methane efficient sheep (Kirby, NSW) to assist/accelerate the development of similar protocols for Kirby and their similar testing on MLA Resource Flock sheep.

Calculation of feed intake traits

After cleaning, the data is summarised into individual daily intake for each sheep. A total of 748 sheep had between 2-31 days of full intake data recorded. All sheep with >40% coefficient of variation in daily intake were removed as accurate/stable traits couldn't be estimated with confidence (n=41 or 5.5% of records).
*Note: all 41 sheep removed had 10 or more full days of intake data and 50% of those removed were dorpers.

Two estimates of average daily intake were calculated:

(1) Voluntary Potential Intake (VPI; kgDM/hd/day): Average daily intake using full intake days only (24 hours of continuous intake events from 12:00am to 12:00am)
(2) Average Daily Intake (ADI; kgDM/hd/day): Average daily intake using full intake days as well as part-intake days (where technology failures caused intake to be restricted or unrecorded during the 24-hour period between 12:00am and 12:00 am)

The latter intake trait (ADI) was 1% or 160g lower on average for the 2022 cohort and 14% or 279g less on average for 2023 cohort and added approximately 7 days of extra intake data on average across all sheep. The two different feed intake calculations were 92% correlated and there were no significant differences between covariates between models using ADI or VPI. Using ADI increased the variation explained by an average of 10% across all six kill groups (range 0-30%). Part record collection was caused mostly by laser misalignment (resulting in restricted intake) or secondarily by connectivity/power interruption. ADI is likely closer to the real intake relating to mid weight and growth, with VPI describing total potential daily intake under *ad libitum*. Both traits have been submitted to Sheep Genetics.

Residual Feed Intake

Residual feed intake was estimated using multiple linear regression. Average daily intake (ADI) was adjusted by fitting (1) mean metabolic mid weight; MMWT and (2) Average Daily Gain as covariates.

(1) MMWT = the predicted mid weight during the feed intake test calculated via linear regression of the twice weekly weights throughout the intake test.
(2) ADG = the slope of the linear regression used to calculate MMWT.

The unexplained variation after fitting this model was the residual feed intake. Each kill group was modelled separately with pen fitted as group. Date of birth, birth type and sex were added and dropped from all models as their effects were insignificant (excepting one model/kill group) in addition to mean metabolic mid weight and growth.

3.2.4 Methane

Post-weaning gas production (CH_4, CO_2 and O_2) using Portable Accumulation Chambers (PACs) was captured from all lambs during December 2022 (n= 929) and December 2023 (n=899) in alignment with project P.PSH.2011. A second methane measurement was completed prior to slaughter for kill groups 2-4 for both cohorts (n=1300; Figure 1, Table 2). There was insufficient time between the post-weaning measurement and the first kill booking date for the first kill groups of either cohort to have a second methane measurement completed prior to slaughter. In both years, pasture on-farm had senesced, therefore all progeny were supplemented with specially formulated grower pellets and oaten hay (Table 4) in 2022, and oaten hay and a 70% oat- 30% lupin mix in 2023 (Table 5). Post weaning gas production was measured over two weeks in early-mid December each year.

Table 4. Nutritional test results for the pasture, pellets and hay provided to progeny during methane testing in December-22.

	Pasture	Pellets	Hay
Dry matter (%)	75.8	91.6	89.9
Moisture (%)	24.2	8.4	10.1
Crude Protein	5.9	14.2	7.1
Acid detergent fibre (%)	43.1	20.4	37.3
Neutral detergent fibre (%)	78	37.8	67.3
Digestibility of dry matter (%)	48	70.1	49
Digestibility of organic dry matter (%)	47.5	69.4	48.3
Metabolisable energy (MJ)	6.6	11.6	6.8
Fat (%)	2.3	4.3	3.3
Ash (%)	6.6	5	6.1

Table 5. Nutritional test results for the oats, lupins and hay provided to progeny during methane testing in December-23.

	Oat Batch 1	Oat Batch 2	Lupin Batch 1	Lupin Batch 2	Hay Batch 1	Hay Batch 2
Dry matter (%)	90.6	89.8	92.8	92.6	89	92.9
Moisture (%)	9.4	10.2	7.2	7.4	11	7.1
Crude Protein	9.7	10.3	36.1	29.4	5.9	5.7
Acid detergent fibre (%)	21.5	13.8	14.1	19.9	32.1	30.9
Neutral detergent fibre (%)	41.3	32.3	23.3	30.4	65.3	57.9
Digestibility of dry matter (%)	62.0	71.9	87.6	82.9	57.3	60.7
Digestibility of organic dry matter (%)	61.7	71.2	86.3	81.8	55.3	58.3
Metabolisable energy (MJ)	11.3	13	14.7	14.1	8.2	8.8
Fat (%)	6.9	8.5	7.2	7.3	3.6	3.7
Ash (%)	2.9	2.8	3.1	3.9	3.1	5.2
Starch (%)	35.1	52.6				
Sugars (%)	1.2	1.3				

Prior to assessing methane, the progeny were managed in two groups with the Dorpers separate to the Merino/Maternal/Terminal flock. On the day of methane testing, the two flocks were drafted into groups of 16 prior to assessment. Time off-feed ranged between 1-5 hours. A minimum of 6 and a maximum of 11 runs of methane measurements were completed on any day (16x sheep per run). The sheep were moved into a sunken race filled with approximately 1 inch of water and a Portable Accumulation Chamber (PAC) was lowered over each animal using marine ropes and pulleys, for a total of 45 minutes per run. Ambient temperature, pressure and humidity was recorded at the start and end of each run. Temperatures inside the PAC were measured at the start and end of each run. Methane, carbon dioxide and oxygen levels were recorded inside and outside the PACs every fifteen minutes (total of 3 PAC measurements over 45 minutes). All non-linear methane accumulation was removed prior to analysis (approximately up to 2% of records).

Gas production was measured using an Eagle 2 gas analyser. The ability of each PAC to retain gas was assessed within one week prior to and following methane measurements to ensure accuracy of results. Prior to each run, and between each 15-minute measuring interval, the Eagle 2 was tested against standards of known CH_4, O_2 and CO_2 concentrations.

CH_4 production, O_2 and CO_2 rates were determined using the following calculations:

- The volume of the PAC is calculated from internal measurements and equals 819 litres
- Volume of 'air' in chamber is calculated as (819 – liveweight kg) x STP correction
- STP= (273.1)/(273.1 + (average PAC temp)) x (average pressure kpa /101.3)
- Average PAC temp= (PAC temp at start + PAC temp at end)/2
- Average pressure kpa = ((Pressure hpa at start + pressure hpa at end)/2)/10

Then methane production is calculated by:

- CH_4 mL/min = ((CH_4 ppm – background CH_4)*(0.819-liveweight kg/1000))/time in PAC*STP

And carbon dioxide production (%) and oxygen consumption (%) is calculated by:

- CO_2 mL/min = ((CO_2 ppm – background CO_2)*(0.819-liveweight kg/1000))/time in PAC*STP
- O_2 mL/min = ((O_2 ppm – background O_2)*(0.819-liveweight kg/1000))/time in PAC*STP

3.3 Statistical Analysis

Stability of the intake trait was estimated using variance and correlation calculations. Daily intake was calculated by summing the total feed eaten over each day. The project compared the variance of intake measured over 1, 2, 3, to 30 days. It also estimated the correlations of feed intake measured of different time periods to feed intake measured over 30 days.

Residual Feed Intake was calculated using multiple linear regression for each kill group mean metabolic mid-weight and growth during the feed intake period fitted as fixed effects, pen fitted as group and dam fitted as a random effect. (Mean metabolic weight was calculated for the halfway point for each group using linear regression to predict the intercept and slope from the ten weights (approximate) taken over the feed intake test.). Residual Feed Intake efficiency was calculated by subtracting the fitted values from the multiple linear regression model for intake from the actual average daily intake recorded for each sheep.

Residual Maximum Likelihood was used to test feed intake for significant sire effects for each cohort separately. Kill group, mean metabolic mid weight and growth (plus all significant two-way interactions) and sire were fitted as fixed effects with dam and pen fitted as random effects. All non-significant terms were dropped from the final model(s).

4. Results

4.1 Growth

Separation into kill groups occurred early in the year and was based on liveweight with heavier lambs allocated to earlier kills and sires balanced across all kill groups. Hence the last kill group tended to be the lighter lambs from early post-weaning with slower overall growth rates between weaning and slaughter (Table 6). Growth rates over the first methane measurement (M1; Table 6) were poorly correlated (<1%) with growth rates pre-slaughter (PS; Table 6) for both cohorts, likely to be due partly to fewer weights and longer time period associated with the first methane growth rate (3 weights over two months) versus the pre-slaughter growth rate (>10 weights over one month).

Table 6. The number, age and growth over their first methane measurement (M1), between weaning and slaughter (PW) and over the feed intake period pre-slaughter (PS) of the four kill groups of the 2022&2023-born lambs from the MLA Resource Flock at Katanning.

	GrowthM1 (kg/hd/day)	GrowthPS (kg/hd/day)	ADG (kg/hd/day)
2022 born			
1 (n=192)	0.164 ± 0.004	0.174 ± 0.003	-
2 (n=231)	0.206 ± 0.004	0.191 ± 0.004	0.225 ± 0.008
3 (n=230)	0.181 ± 0.004	0.177 ± 0.002	0.186 ± 0.007
4 (n=239)	0.148 ± 0.004	0.157 ± 0.002	0.192 ± 0.005
2023 born			
1 (n=198)	0.213 ± 0.005	0.190 ± 0.003	-
2 (n=240)	0.172 ± 0.003	0.236 ± 0.005	0.244 ± 0.006
3 (n=204)	0.197 ± 0.004	0.189 ± 0.004	0.187 ± 0.006
4 (n=241)	0.172 ± 0.004	0.179 ± 0.006	0.079 ± 0.007

4.2 Body composition

Changes in body composition were estimated by the difference between eye muscle and fat depth measured at early post-weaning age and then again immediately prior to slaughter. While changes detected were similar across cohorts, the 2022 cohort appeared to be fatter at both measures even when factoring in differences in age and weight (WTps; Table 7), which is likely due in part to pellet feeding commencing at weaning time (much earlier) for this cohort. Changes in body composition between post-weaning and pre-slaughter measurements were greatest for the last kill group, which is expected given their increased age/maturity and weight (Table 7).

Table 7. Changes in eye muscle and fat depth between early post-weaning (pw) and pre-slaughter age (ps) of lambs from the MLA Resource Flock at Katanning.

2022-born	EMDpw (mm)	EMDps (mm)	EMD change (mm)	Fatpw (mm)	Fatps (mm)	Fat change (mm)	Age at slaughter (days)	WTps (kg)
Kill 1	27.9	27.8	0	3.3	3.2	0	211	48.7
Kill 2	25.8	28.8	3	3.1	5.5	2	249	55.8
Kill 3	24.2	29.7	6	2.8	5.9	3	286	57.9
Kill 4	21.8	30.4	9	2.4	6.0	4	318	56.7
2023-born								
Kill 1	26.3	-	0	2.9	-	0	185	48.3
Kill 2	23.5	27.4	4	2.3	3.7	1	215	46.4
Kill 3	24.5	30.8	6	2.3	4.8	2	262	48.4
Kill 4	21.2	29.0	8	2.0	4.4	2	307	53.4

4.3 Feed intake

Variation in daily feed intake became stable in less than 30 days (Figure 2), with correlations around 0.95 after 20 days (Figure 3), consistent with previous reporting for Merinos (Macleay et al. 2014). The correlation coefficients were used for sheep with more than 25 days intake (n=155) to set accuracy parameters for the feed intake trait across the larger dataset. Consequently, intake trait has been submitted to Sheep Genetics for 748 sheep with accuracies of the trait varying between 50.5% to 99.8% with a majority of intake measurements (95%) having >80% accuracy.

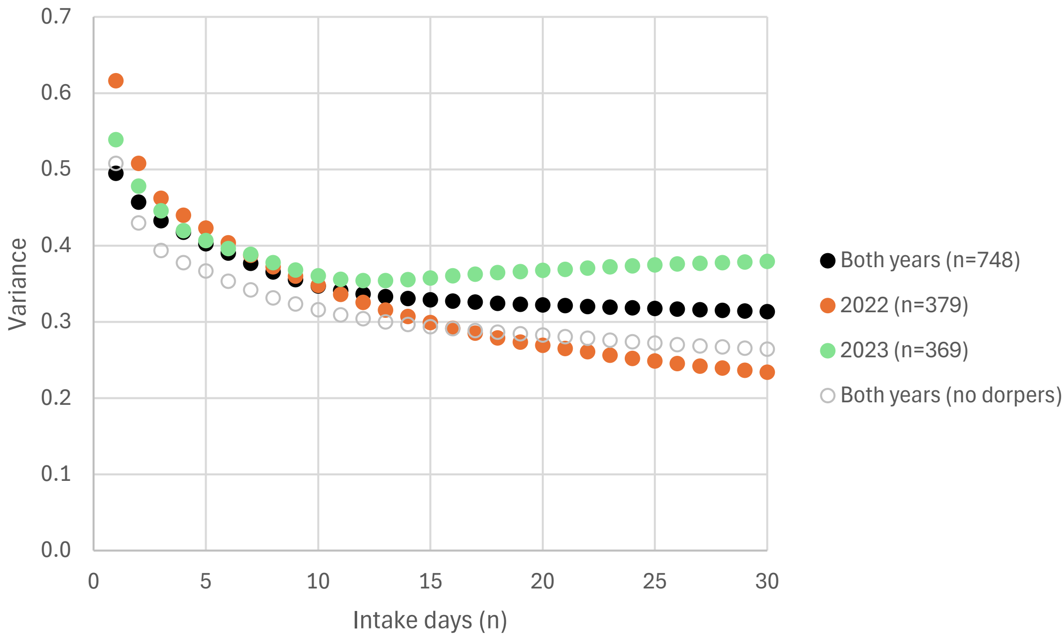


Figure 2. The combined and separate variance in average daily intake for the 2022-born and 2023-born lambs from the MLA Resource Flock measured for up to 30 days pre-slaughter.

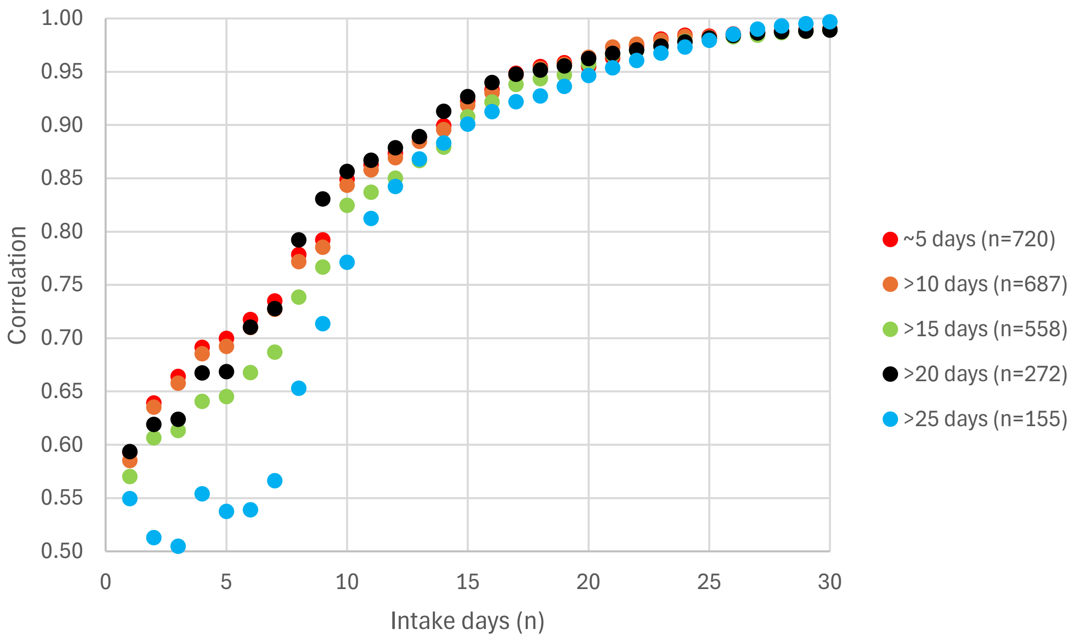


Figure 3. The correlation between 2-30 days of average daily intake with average daily intake intake of up to 30 days for the 2022-born lambs from the MLA Resource Flock.

The variance in average intakes was higher for the 2023 cohort than the 2022 cohort. The measurement of an entire kill group of dorpers in 2023 contributed to much higher variance in intake observed in the 2023 cohort than the 2022 cohort. Interestingly, the exclusion of dorpers shows a reduction in variance in intake from about 0.37 to 0.26 (Figure 2).

Figure 3 shows the variance in intake of all lambs measured for 2-30 days with the variance of just the lambs measured for at least 30 days. For example the blue dots are sheep that had 25 or more days of intake measured, black dots are sheep that had 20 days or more of intake measured etc. Sire variation in the stabilisation of intake was also evident (Figure 4).

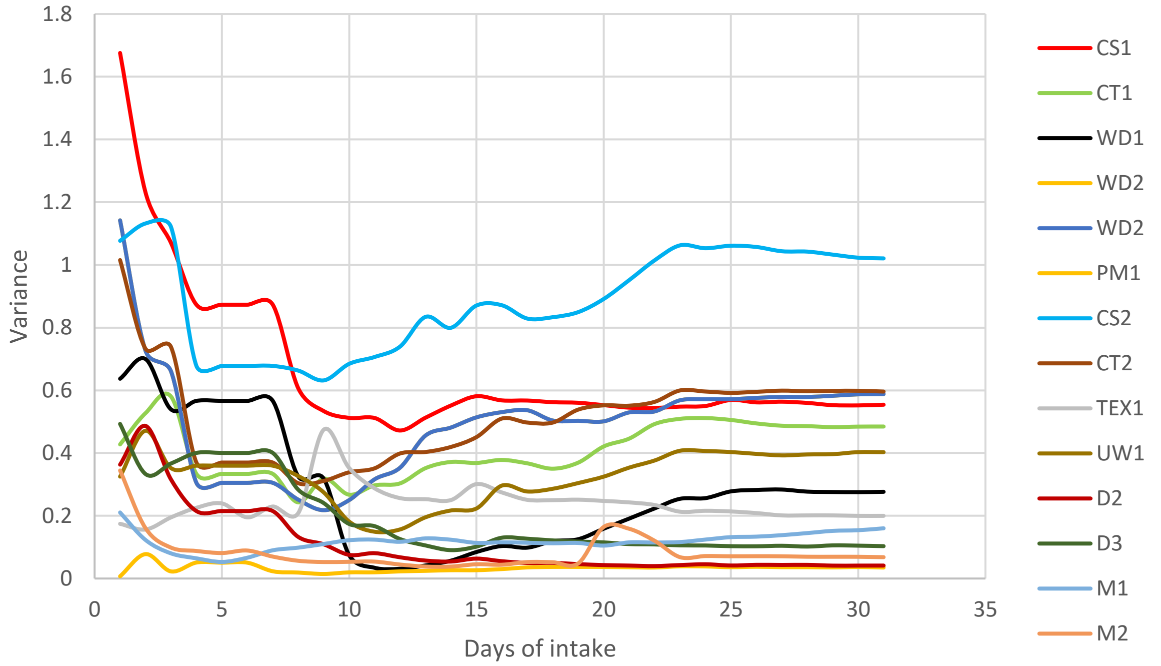


Figure 4. The variance in average daily intake of some example sires (2-8 progeny per sire) from the MLA Resource Flock.

The overall stabilisation in intake in less than 30 days is a promising result as technical disruptions such as power and laser misalignments in DPIRD facilities reduce the number of entire days (24 hours) where intake is recorded completely. Laser misalignment was the primary cause of intake recording disruptions. The system relies on a laser beam, interrupted by the sheep's head entering the feeder, to trigger the feed hopper. However, aggressive feeding behaviour or the movement of some sheep can displace the sensors, preventing beam interruption and causing the feeder to remain closed. This results in restricted feed access for the affected pen until on-site technicians identify and resolve the issue. More sheep will have a valid intake trait if the test length can be reduced and/or if restricted/part-day records for intake can be used. In growing beef cattle the removal of more than 40% of their intake data (1-3 days per week over a 10 week test period) did not change their average daily intake estimate significantly, provided the intake data removal was random rather than blocked e.g. consecutive days (Hebart et al. 2004).

For this project, across all the groups measured, average days affected by data loss across the ten recording pens was 27% (range 11-55% per year x group x pen), so mostly within the acceptable range identified by Hebart et al. (2004). To further test the stability of our trait we compared models using just (complete) intake data as well as part records and the feed intake trait that included part-records improved the model estimates by 10% (average, range 1-30%) across all six kill groups measured. This further supported inclusion of part-records to quantify the intake trait for the sheep measured and the submission of two intake traits for the sheep measured, one estimating average daily intake (ADI) and a second trait estimating voluntary potential intake (VPI) the latter including only data from days where continuous recording of 24 hours of intake was achieved.

4.3.1 Residual Feed Intake

Average daily intakes varied between 1.4 and 1.9 kg/hd/day between kill groups across both cohorts for the month prior to slaughter (Table 8). Mean residual feed intake was more variable for the first kill group through the shed (Table 9), which is likely due (in-part) to establishment and tweaking of systems and processes across the first full shed of sheep (post-commissioning). Excepting this first kill group, variation between minimum and maximum residual feed intake averages between pens was consistently around 0.7-0.8 kg for each kill group (Table 9).

Table 8. The growth pre-slaughter (PS), Average daily intake (ADI), Voluntary Potential Intake (VPI) and mean metabolic mid weight of the four kill groups of the 2022&2023-born lambs from the MLA Resource Flock at Katanning.

	GrowthPS (kg/hd/day)	ADI (kgDM/day)	VPI (kgDM/day)	Mid weight (kg)
2022 born				
1 (n=192)	-	-	-	-
2 (n=231)	0.225 ± 0.008	1.70 ± 0.041	1.90 ± 0.034	55.8 ± 0.577
3 (n=230)	0.186 ± 0.007	1.68 ± 0.024	1.88 ± 0.025	57.9 ± 0.563
4 (n=239)	0.192 ± 0.005	1.44 ± 0.032	1.58 ± 0.032	56.7 ± 0.548
2023 born				
1 (n=198)	-	-	-	-
2 (n=240)	0.244 ± 0.006	1.87 ± 0.039	2.09 ± 0.048	46.7 ± 0.512
3 (n=204)	0.187 ± 0.006	1.85 ± 0.027	1.90 ± 0.031	48.5 ± 0.620
4 (n=241)	0.079 ± 0.007	1.56 ± 0.026	1.69 ± 0.025	53.2 ± 0.710

Table 9. Maximum and minimum residual feed intake (pen averages) for the four kill groups of lambs born in 2022 and 2023 from the MLA Resource Flock at Katanning.

	RFI Max. (kg/hd/day)	RFI Min. (kg/hd/day)	Breed comment
2022 born			
1 (n=192)	-	-	Dorpers
2 (n=231)	0.727	-0.732	30% Merino
3 (n=230)	0.367	-0.314	35% Merino
4 (n=239)	0.563	-0.486	35% Merino
2023 born			
1 (n=198)	-	-	18% Merino
2 (n=240)	0.250	-0.453	31% Merino
3 (n=204)	0.435	-0.337	Dorpers
4 (n=241)	0.350	-0.343	39% Merino

Weight and growth explained 72-89% of the variation observed in daily feed intake (Table 10), consistent or better than previous reports for sheep (Paganoni et al. 2014). Mean metabolic mid weight had the greatest and most significant effect on feed intake across most of the kill groups with consistent increase in intake of 60-70g for every 1kg increase in weight (P<0.05; Table 10). Growth had additional significant positive effects to mid weight for four of the six kill groups measured (P<0.05; Table 10). For every 1g/hd/day increase in growth rate there were additional increases in daily intake of 1.5-2g per day (P<0.05; Table 10). There were no significant effects of birth type or sex on feed intake (beyond differences accounted for by mean metabolic mid-weight). Age had a small significant additional effect on feed intake for one of the six kill groups measured (19g of additional intake/day per day older at slaughter, P<0.05; Table 10). Body composition measured by ultrasound scanning of muscle and fat pre-slaughter had no significant effects on feed intake. There were also no significant relationships detected between average daily feed intake and methane production measured via Portable Accumulation Chambers pre-slaughter (Table 10).

Table 10: Estimates of significant terms from the linear regression model for residual feed intake for the kill groups 2-4 of the 2022&2023-born lambs from the MLA Resource Flock at Katanning. The variation accounted for by the significant model terms appears in brackets (%).

2022	Mid-weight	Growth	Sex	Birth type	Date of Birth	Eye muscle Depth	Fat	Methane
2 (89%)	0.11 ± 0.004	n.s.	n.s.	n.s.	0.019 ± 0.005	n.s.	n.s.	n.s.
3 (72%)	0.07 ± 0.025	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4 (84%)	0.06 ± 0.022	1.52 ± 0.730	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
2023								
2 (89%)	n.s.	1.81 ± 0.840	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
3 (75%)	0.07 ± 0.026	2.03 ± 0.794	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4 (77%)	0.06 ± 0.018	1.53 ± 0.804	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

There appeared to be some sire differences at the extremes of intake for the 2022 cohort. Figure 5 shows the predicted means for intake for ten extreme sires with three or more progeny measured for intake. For this cohort 99 sires were represented amongst the intake measures with an average of 3.4 progeny per sire (range 2-7 progeny per sire). For the 2023 cohort there were 101 sires represented for intake with an average of 3.0 progeny per sire (range 2-8 progeny per sire). There were no significant sire differences detected between the progeny measured in the 2023 cohort. Sires from all breed types were represented at the extreme ends of residual feed intake.

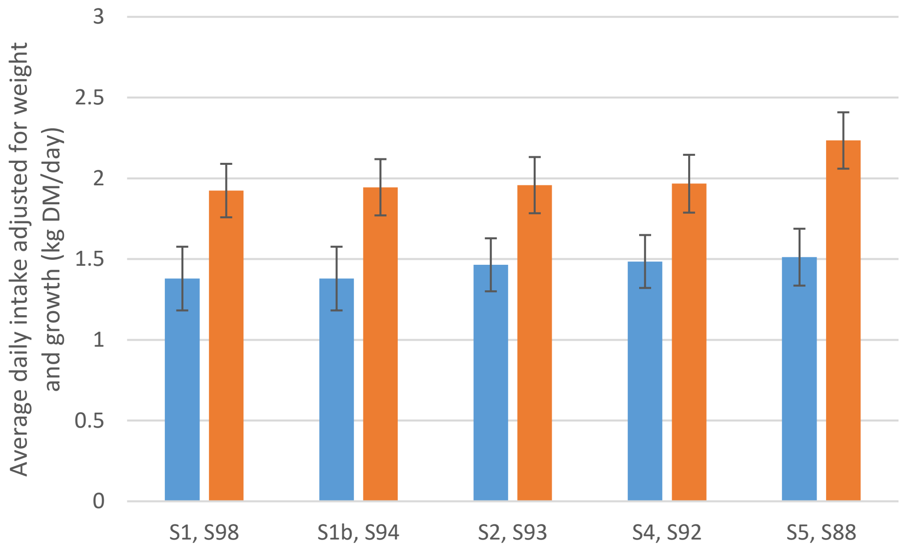


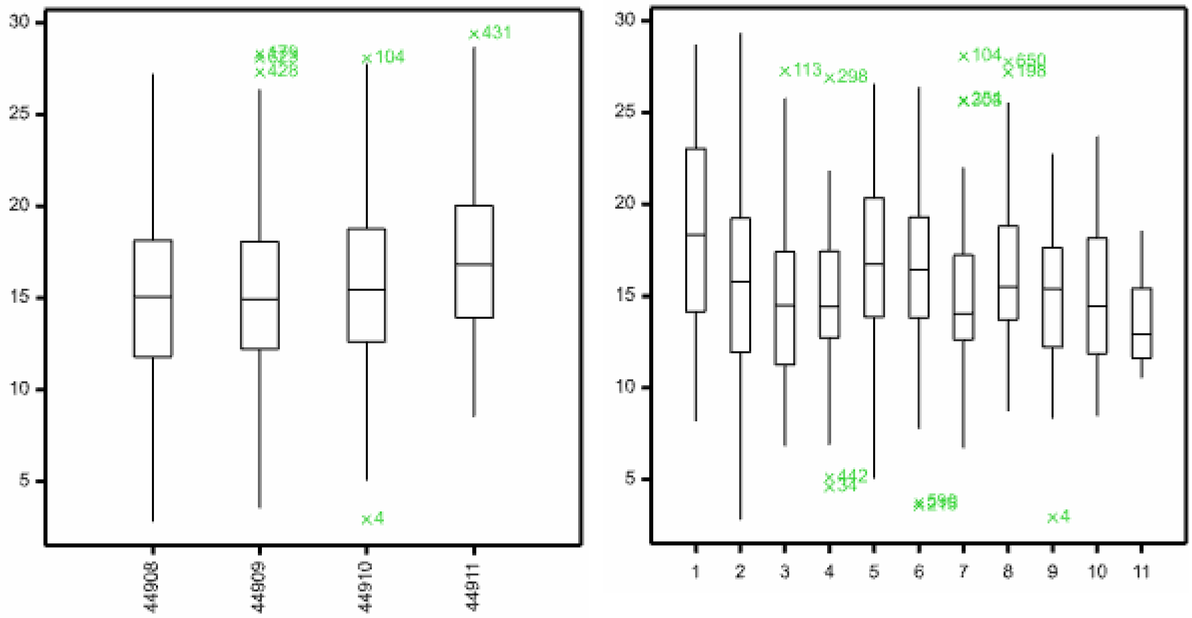
Figure 5. Sire predicted means (± standard error) for average daily intake adjusted for weight and growth of the 2022-born lambs from the MLA resource flock (n=3-5 progeny per sire).

4.4 Methane

Methane production decreased with time off feed as indicated by the split effect of run within day for the post-weaning measurements, typical of on-farm protocols for measuring methane via PACs (Figure 6). For the pre-slaughter methane measurements runs were represented by pens, which were grouped by similar starting liveweight and is evidenced by a contrasting apparent increasing effect of methane production with run, despite time off feed being uniform (Figure 7).

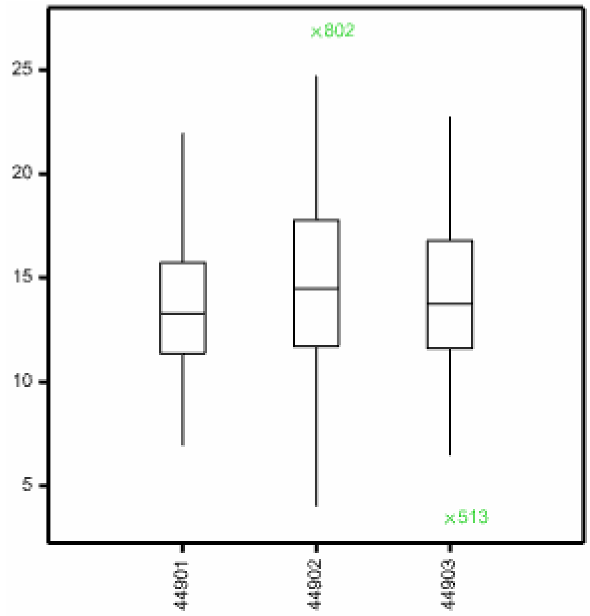
A) 2022 born MMT lambs by day

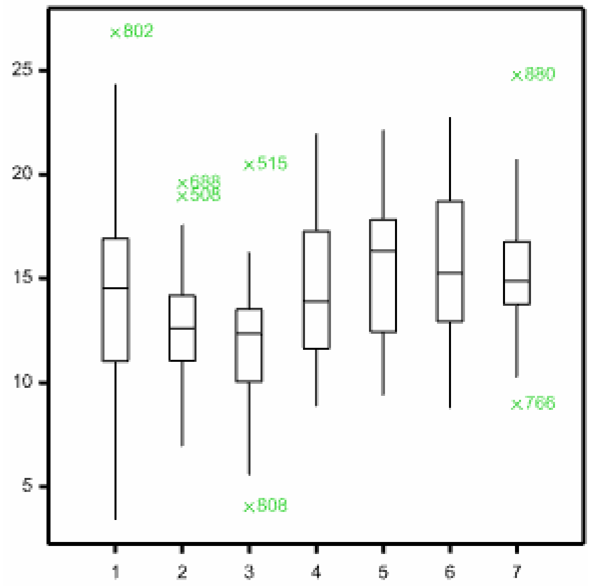
B) 2022 born MMT lambs by run



C) 2022 born DORP lambs by day

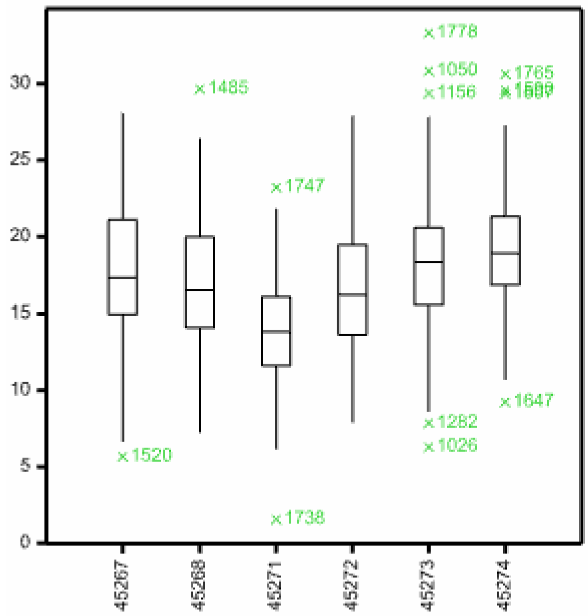
D) 2022 born DORP lambs by run



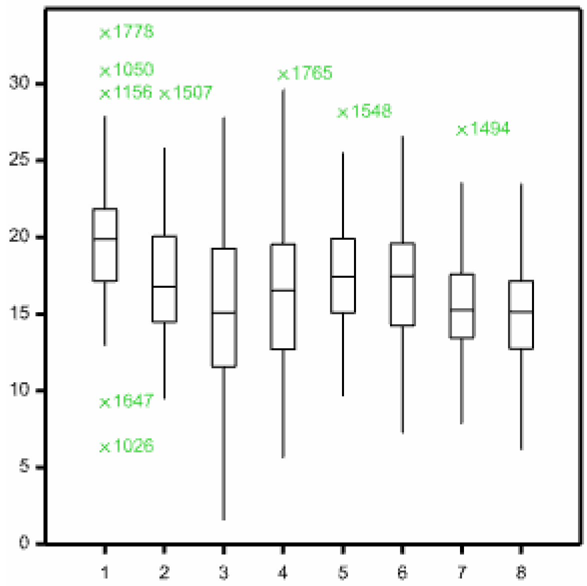


E) 2023 born MMT by day

F) 2023 born MMT lambs by run



G) 2023 born DORP lambs by day



H) 2023 born DORP lambs by run

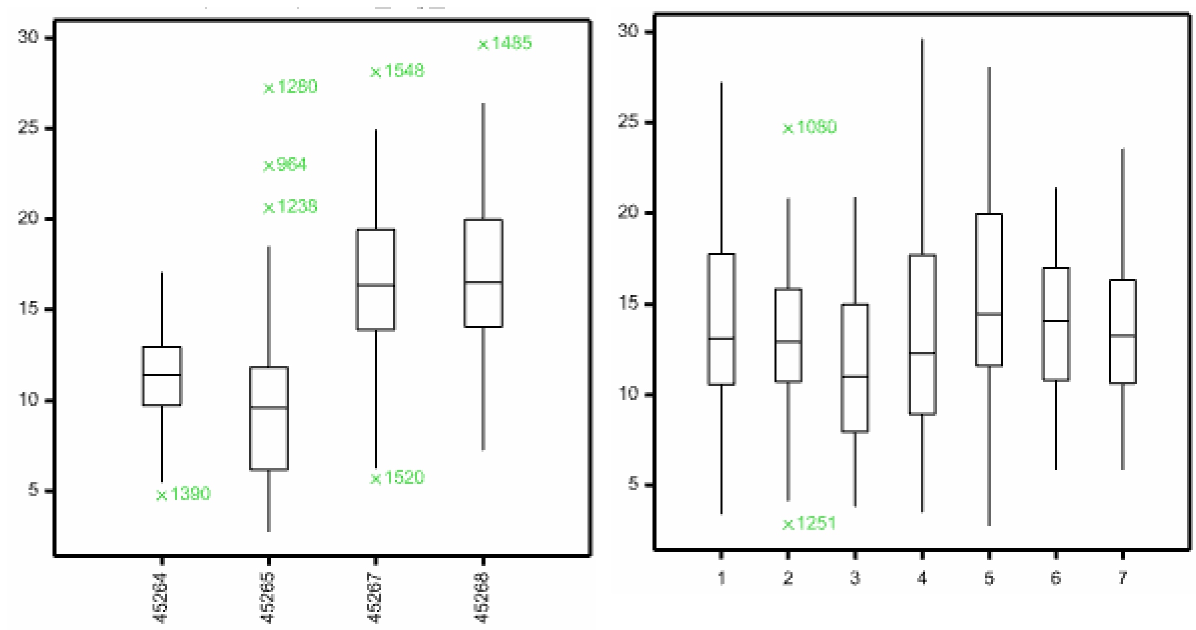
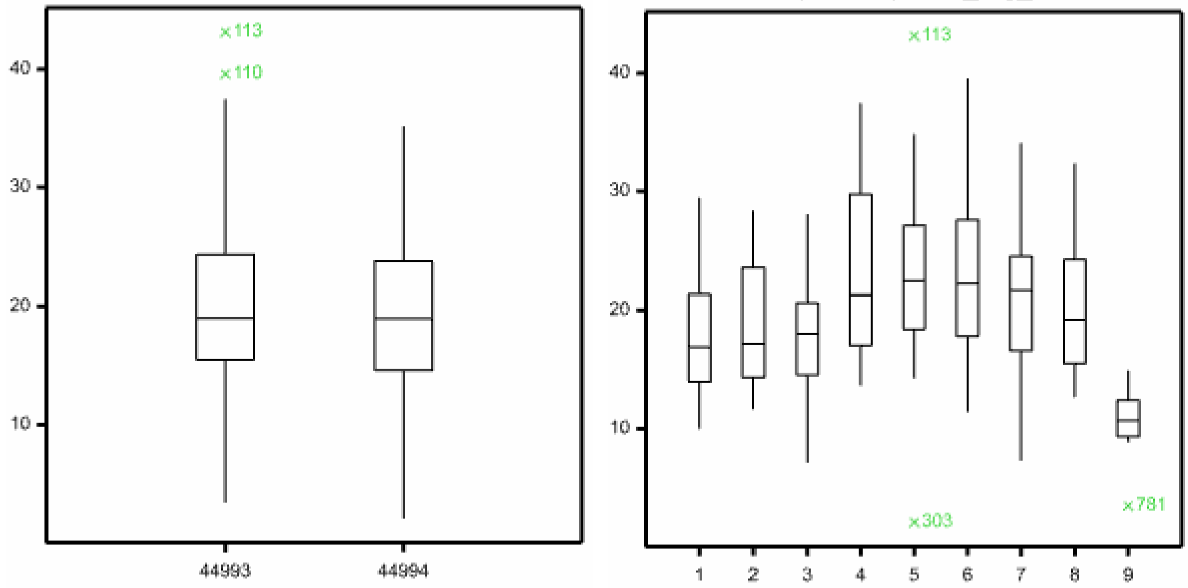


Figure 6. Methane (mg/min, y-axis) averages and standard deviation for day and run within day (x-axis) MLA Resource Flock lambs from Merino/Maternal ewes (MMT) and Dorper ewes (DORP) measured at early post-weaning age via PACs in 2022 and 2023.

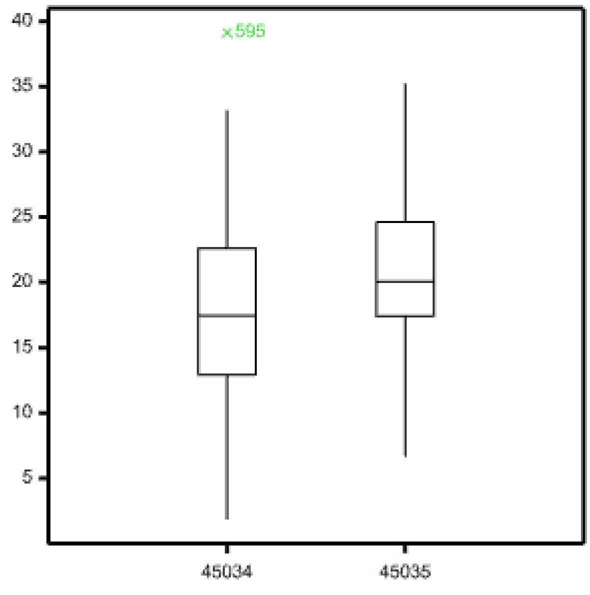
A) 2022 born kill2 lambs by day

B) 2022 born kill2 lambs by run

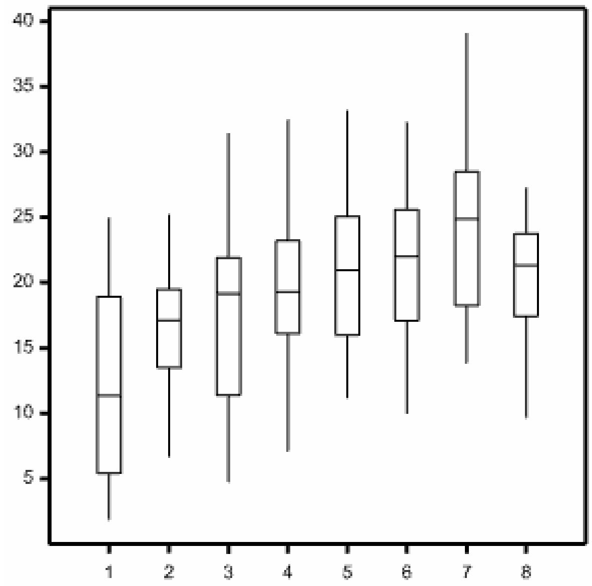


A) 2022 born kill3 lambs by day

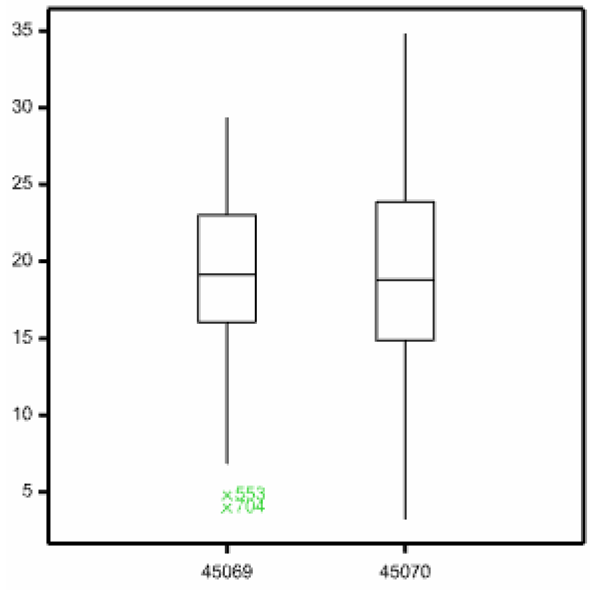
B) 2022 drop kill3 lambs by run



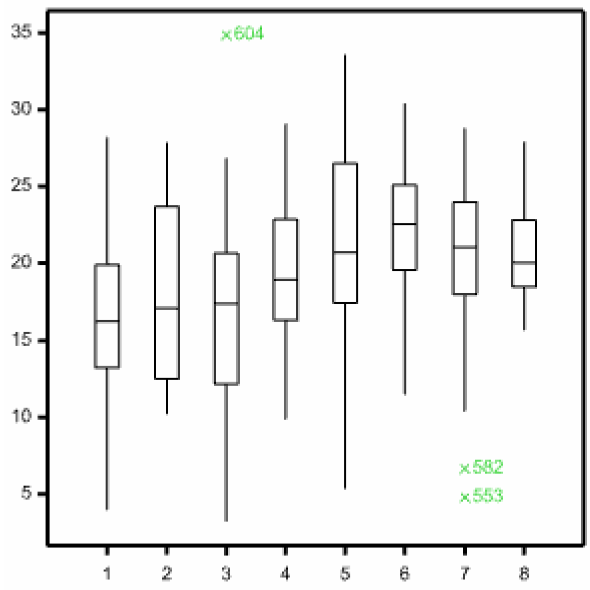
A) 2022 born kill4 lambs by day



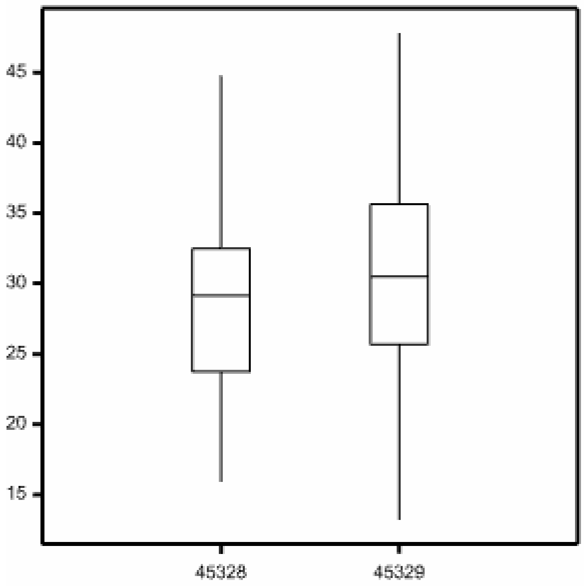
B) 2022 born kill4 lambs by run



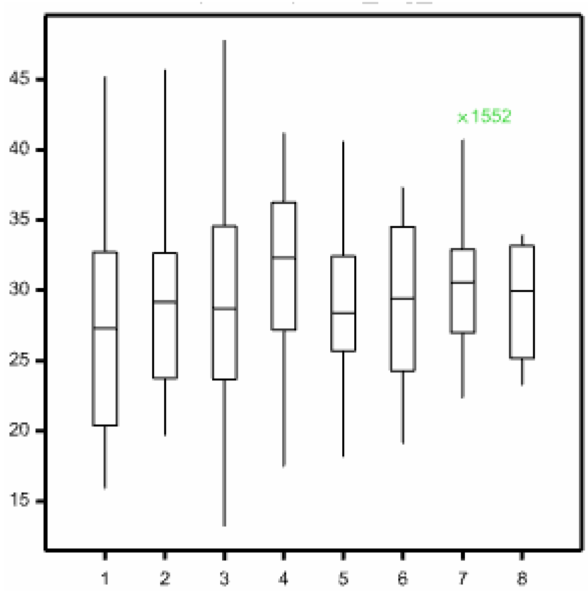
A) 2023 born kill2 lambs by day



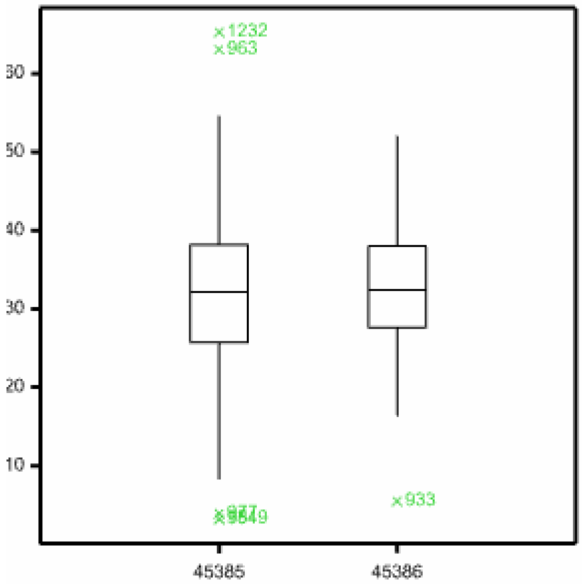
B) 2023 born kill2 lambs by run



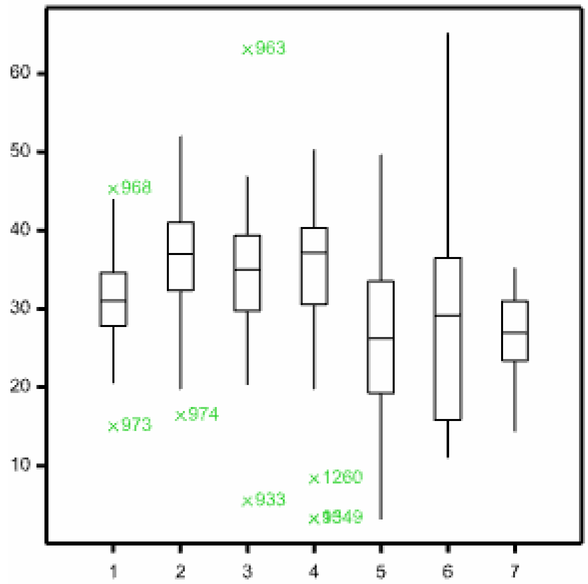
A) 2023 born kill3 lambs by day



B) 2023 born kill3 lambs by run



A) 2023 born kill4 lambs by day



B) 2023 born kill4 lambs by run

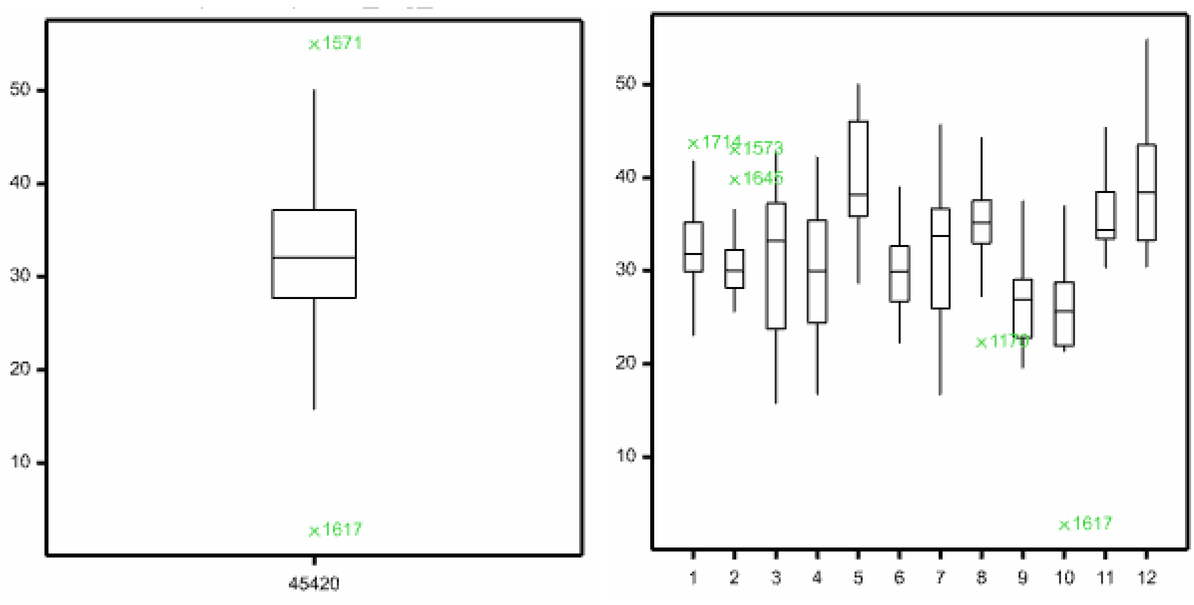


Figure 7. Methane averages (mg/min, y-axis) and standard deviation for day and run within day (x-axis) for MLA Resource Flock lambs born in 2022 and 2023 and measured prior to slaughter in three kill groups via PACs.

Average methane production and liveweights were very similar across cohorts for the early post-weaning measurement (Table 12). For the pre-slaughter methane measurement, the average liveweight of the 2022 cohort was heavier however their methane production was significantly lower (Table 12). Correlation (phenotypic) between the post-weaning and pre-slaughter measures was approximately 30% for the 2022 cohort, aligned with reported phenotypic predictions for sheep (Paganoni et al. 2017; Robinson et al. 2020). Correlation between the post-weaning and pre-slaughter measurements for the 2023 cohort was lower (approximately 10%). Differing nutrition and adaptation time to a pelleted diet could be contributing factors.

The 2022 cohort were supplemented with a consistent pellet across both methane measurements (Tables 3 and 4), while the 2023 cohort received grain and hay over the first measurement (Table 4) and were adapted to a pellet that measured higher in roughage for the pre-slaughter measurement (Table 3). Nutritional testing of the pellets fed to the 2023 cohort had significantly higher NDF content (46%) than for previous batches (35%) as well as lower ME (10 versus 11.5MJ/kgDM), which was verified with secondary sample testing. This resulted in significantly higher methane production for the 2023 cohort per kg of liveweight ($P<0.05$). Liveweight variation at slaughter were similar between cohorts (Figure 8) and when methane production was proportioned to the estimated roughage intake for lambs with available ADI data, methane production pre-slaughter was more consistent between kill groups with kill group 4 producing the highest average methane per kg of roughage intake over both years (Table 11).

Table 11. The average age, numbers measured (No.) and average methane (ch4) measured post-weaning and pre-slaughter using production via portable accumulation chambers for lambs born in 2022 and 2023 from the MLA Resource Flock.

Drop	Breed/grp	Age (days)	No.	ch4 (mg/min)	ch4 (mg/min/kgNDF)	liveweight (kg)
Post-weaning measurement						
2022	DORP	140	300	14.2 ± 0.22		37.3 ± 0.35
2022	MER/MAT	155	619	15.8 ± 0.19		36.2 ± 0.29
2023	DORP	136	213	10.6 ± 0.25		31.2 ± 0.32
2023	MER/MAT	151	685	16.9 ± 0.17		38.4 ± 0.25
Pre-slaughter measurement						
2022	kill2	238	215	20.0 ± 0.46	24.0 ± 1.41	59.0 ± 0.64
2022	kill3	279	227	18.9 ± 0.46	20.1 ± 0.82	60.4 ± 0.64
2022	kill4	314	220	19.2 ± 0.40	28.3 ± 1.34	59.6 ± 0.59
2023	kill2	200	232	29.6 ± 0.42	19.7 ± 0.67	51.2 ± 0.39
2023	kill3	257	189	31.6 ± 0.75	21.5 ± 0.72	53.8 ± 0.48
2023	kill4	301	191	32.4 ± 0.54	31.3 ± 1.12	56.5 ± 0.51

*methane (mg/min/kgNDF) is the amount produced per roughage proportion (%) of average daily intake (kg/hd/day) measured on approximately half the lambs from each kill group prior to slaughter

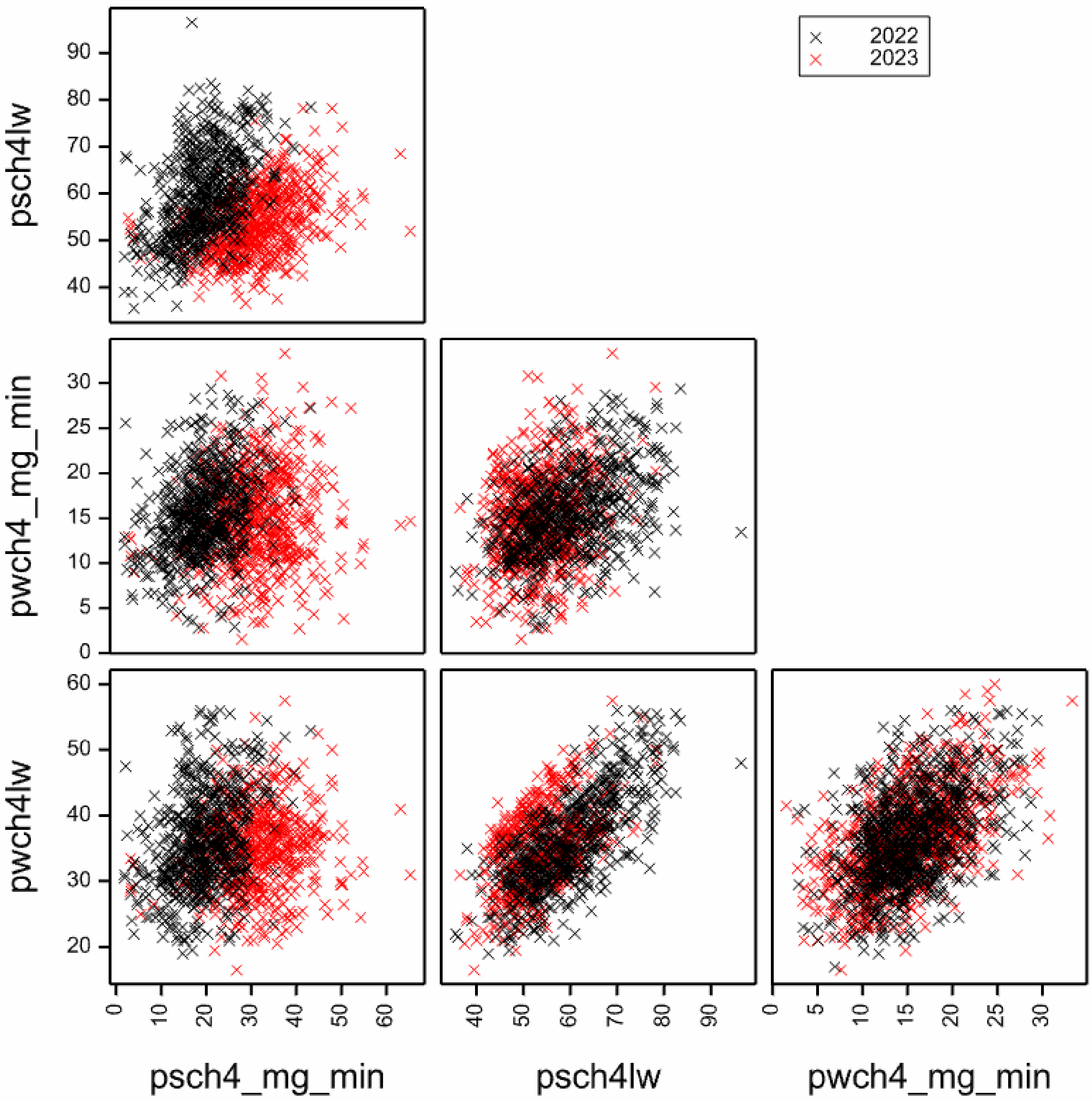


Figure 8. Liveweight (lw; kg) and methane (ch4; mg/min) measured via portable accumulation chambers and at early post-weaning (pw) and pre-slaughter (ps) for lambs from the 2022 and 2023-born MLA Resource Flock at Katanning.

Table 12. Correlations between sire means for liveweight at post-weaning methane (lwpsch4), post-weaning methane (pwch4), early post-weaning growth (epwgrowth), average daily intake (ADI), mean metabolic mid weight (mmwt), pre-slaughter growth (psgrowth), pre-slaughter methane (psch4), pre-slaughter eye muscle depth (psemd) and pre-slaughter fat (psfat) for MLA resource flock lambs born in 2022.

2022	pwch4lw	epwgrowth	pwch4	ADI	mmwt	psgrowth	psch4	psemd	psfat
pwch4lw	-								
epwgrowth	0.75	-							
pwch4	0.60	0.55	-						
ADI	0.52	0.40	0.26	-					
mmwt	0.82	0.76	0.62	0.55	-				
psgrowth	0.04	-0.02	0.04	0.14	0.04	-			
psch4	0.49	0.42	0.51	0.35	0.53	0.25	-		
psemd	0.76	0.69	0.48	0.45	0.82	0.05	0.50	-	
Psfat	0.54	0.58	0.55	0.42	0.74	-0.06	0.45	0.62	-

P<0.05 = dark grey; n.s. = no shading

Table 13. Correlations between sire means for liveweight at post-weaning methane (lwpsch4), post-weaning methane (pwch4), early post-weaning growth (epwgrowth), average daily intake (ADI), mean metabolic mid weight (mmwt), pre-slaughter growth (psgrowth), pre-slaughter methane (psch4), pre-slaughter eye muscle depth (psemd) and pre-slaughter fat (psfat) for MLA resource flock lambs born in 2023

2023	pwch4lw	epwgrowth	pwch4	ADI	mmwt	psgrowth	psch4	psemd	psfat
pwch4lw	-								
epwgrowth	0.40	-							
pwch4	0.65	0.13	-						
ADI	0.28	0.34	0.05	-					
mmwt	0.69	0.51	0.40	0.40	-				
psgrowth	0.26	0.19	0.18	0.48	0.17	-			
psch4	0.33	0.33	0.25	0.33	0.52	0.27	-		
psemd	0.43	0.36	0.03	0.45	0.61	0.14	0.43	-	
Psfat	0.38	0.28	0.11	0.47	0.49	0.11	0.40	0.69	-

P<0.05 = dark grey; n.s. = no shading

Average daily intake of sires (n=1-27 per sire) measured pre-slaughter was positively correlated with weight, growth and methane production pre-slaughter and in the early post-weaning period (Tables 12 & 13). Muscle and fat measured pre-slaughter were strongly correlated with mean metabolic weight pre-slaughter, which also had a medium correlation with liveweight and growth in the early post-weaning period (Tables 12 & 13). Sire means for methane production for the post-weaning and pre-slaughter measurements were moderately correlated (raw data means) for the 2022 (0.51; Table 12) and 2023 (0.25; Table 13) cohorts respectively, which aligns with reported genetic correlations for sheep using PACs (Robinson et al. 2020). All methane measurements for both cohorts have been submitted to Sheep Genetics to further inform genetic analyses.

5. Conclusion

The findings of this study provide key insights into the dynamics of feed intake and efficiency traits in sheep. Average daily feed intake stabilises after 15 days, highlighting the feasibility of shorter measurement periods for reliable trait estimation. Incorporating part-record intake data enhances the precision of daily intake estimates, particularly when linked to weight and growth traits. Notably, over 75% of variation in daily feed intake is explained by weight and growth, with methane production and body composition, as measured in this project, contributing minimally. This underscores the central role of weight and growth in driving feed efficiency, under *ad libitum* finishing systems. Importantly, sires across all major breed types exhibit extremes in residual feed efficiency, suggesting broad genetic variability that can be leveraged for selection. Methane output, predominantly influenced by roughage intake, highlights the potential for targeted nutritional and breeding strategies to optimize feed efficiency and environmental outcomes. These findings contribute valuable knowledge to support genetic and management interventions aimed at improving efficiency and sustainability in the red meat industry.

5.1 Key findings

- Average daily intake trait becomes stable in 15 days, potentially reducing measurements costs by 30% for this trait
- Including part-record intake data improved the estimate of the average daily intake trait for weight and growth by 10%.
- A majority (>75%) of daily feed intake variation under *ad libitum* indoor feedlot conditions was attributable to weight and growth, while methane production and body composition had minimal additional influence.
- Sires across all major breed types exhibited extremes in residual feed efficiency for weight and growth, suggesting genetic variability across the national flock that can be leveraged for selection.
- Methane output is largely driven by roughage intake thus selecting for greater feed-use efficiency is likely to also reduce methane production.
- A total of 1,828 genotyped lambs were phenotyped for methane production, growth, and, in some cases, feed intake, alongside their core economic traits (weight, growth, conformation, disease resistance, and carcass quality). This comprehensive data collection significantly enhances sheep genetics research and development.

5.2 Benefits to industry

This project highlights significant progress in understanding feed intake efficiency and methane production in sheep, with over 250 sires represented across key breeds. The findings support that a majority of daily feed intake variation is attributable to weight and growth. Importantly, methane output is strongly linked to roughage intake, and integrating feed intake measurements with methane production offers a powerful dataset to develop breeding values and objectives that producers can utilise. Encouragingly, preliminary results from this project reveal that sires across all major breed types can exhibit extremes in residual feed efficiency, indicating that genetic selection for more efficient and environmentally sustainable meat production is feasible across diverse sheep populations. However, further measurements involving a larger number of sires over multiple years is crucial to strengthen confidence in these relationships and optimize breeding strategies for economic and sustainable gains. The development of robust facilities and protocols marks a pivotal step forward, and maintaining momentum in this research will empower the red meat industry to meet future production targets while reducing environmental impact. These findings hold transformative potential for advancing the efficiency and sustainability of the red meat industry.

6. Future research and recommendations

Future research should focus on validating the reduced intake measurement period to ensure consistent and accurate estimation of feed intake traits across diverse conditions and populations. While preliminary findings are promising, expanding the dataset with additional measurements will solidify confidence in these conclusions and enhance the reliability of breeding values. Addressing challenges related to skilled workforce availability, advanced technology management, and ongoing funding availability is critical for sustaining and expanding this research. The complexity of sophisticated facilities presents an opportunity for the industry to prioritise capacity-building initiatives, attracting and retaining skilled staff to drive genetic advancements. Equally important is investing in the extension of breeding tools and services to producers, ensuring that they understand and adopt new breeding values for feed intake efficiency and methane production. This will enable the industry to translate research findings into tangible economic and environmental benefits, fostering sustainable progress in sheep finishing systems.

7. References

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8. Appendix

8.1 Presentations/extension activities

(1) Wagin Woolorama Trade Stall in DPIRD Shed 2023
(2) Yardstick Field Day – Facilities Tour 2023
(3) AWI and Adelaide University Researchers visit - Facilities Tour 2023
(4) DPIRD Livestock – virtual presentation 2023
(5) Research Presentation UNE, NSW 2023
(6) Research Presentation and Facilities tour for KRS Open Day 2023
(7) ASHEEP Esperance visit – Facilities Tour 2023
(8) Facilities Tour for UNE and NZ researchers 2023
(9) Research Presentation at WALRC Winter Forum 2023
(10) Yr 9/10 Students from Merredin College KRS visit – Facilities Tour 2023
(11)Murdoch University Career Talk 2023
(12) Newdegate Trade Stall 2023
(13) DPIRD Climate Team – Facilities Tour 2023
(14) AAAS feed intake paper presented by Karen Moore 2024
(15) DPIRD Farm Systems Team – Facilities Tour 2024
(16) Murdoch University Career Events 2024 (x2)
(17) Curtin University Careers Expo 2024
(18) Murdoch University KRS Tour 2024
(19) MLA Updates Trade Stall 2024
(20) Yardstick Field Day – Facilities Tour 2024

Posters and project information flyers at trade stalls with other DPIRD staff:

- Perth Royal Show 2023 & 2024, Wagin Woolorama 2024
- Dowerin Field Day 2023 & 2024

- Newdegate Machinery Field Day 2024

8.2 Papers

8.2.1 B Paganoni, B Bolt, A Bowden, P Fitzgerald, SF Walkom and JHJ van der Werf (Submitted 2025). Feed intake and methane efficiency for weight and growth pre-salguhter of MLA resource flock lambs.

FEED-INTAKE AND METHANE EFFICIENCY FOR WEIGHT AND GROWTH PRE-SLAUGHTER OF MLA RESOURCE FLOCK LAMBS.

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SUMMARY

Improving feed-use efficiency and reducing methane emissions in sheep are critical strategies for enhancing market access, profitability, and the long-term sustainability of the sheep industry. In this study, 758 lambs from Merino, Maternal and Shedding ewes mated artificially to Merino, Maternal, Terminal and Shedding sires were assessed for weight, growth, and methane production prior to slaughter across six kill groups (2 years x 3 ages). Weight and growth accounted for 72-89% of the observed variation in daily feed intake. No additional variation was explained by body composition or methane production, as measured in this study. Residual feed intake exhibited high variability across all breed types, suggesting that genetic selection for feed efficiency and methane reduction is achievable across different enterprise types. This research highlights the potential for genetic improvements in reducing methane emissions and enhancing feed efficiency in sheep, offering pathways to a more sustainable and profitable sheep industry.

INTRODUCTION

Efficient use of feed is a critical determinant of productivity and sustainability in livestock systems. Understanding the factors that influence feed intake and efficiency is essential to develop strategies that enhance growth performance, reduce costs, and mitigate environmental footprints.

Breeding sheep that use less feed for the same or more productivity is an attractive solution, however progress is likely to be slow due to the low-moderate heritability (0.1-0.45) of residual feed intake for sheep and trait instability due to feed and environmental variation (Snowder and Van Vleck, 2003; Cammack et al., 2005; Paganoni et al. 2014; Tortereau et al. 2020, Ellison et al., 2022). Centralised research facilities and protocols that can estimate feed intake traits should play a valuable role in increasing trait screening and accessibility to all sheep producers through existing services such as Sheep Genetics Australia and established resource flocks such as the Information Nucleus (Fogarty et al. 2007). Additionally, established resource flocks allow breeders to take advantage of new technology and molecular information to accelerate genetic improvement, exploiting opportunities to simultaneously increase red meat production while reducing emissions.

This study investigated including feed intake, methane output (or emissions) and associated traits and their incorporation to existing resource flock protocols under *ad libitum* feeding pre-slaughter.

MATERIALS AND METHODS

Lambs from the MLA resource flock at Katanning born in July 2022 (n=929) and 2023 (n=899) were measured for methane and body composition at early post weaning age (total=1830) and measured for feed intake (total=758), then methane (n=1300) and body composition (n=1575) a second time prior to slaughter. Kill groups 2,3 and 4 of both cohorts entered indoor feedlot facilities between Jan-May prior to slaughter. In each kill group, approximately half had average daily feed intake captured for approximately 28-32 days.

Table 2. Kill group numbers and dates for the 2022-born and 2023-born cohorts of lambs from the MLA resource Flock at Katanning.

Kill Grp	2022-born		2023-born	
	No.	**Breed**	**No.**	**Breed**
1	224	Dorper	198	Merino/Maternal/Terminal/Dorper
2	231	Merino/Maternal/Terminal/Dorper	240	Merino/Maternal/Terminal
3	231	Merino/Maternal/Terminal/Dorper	204	Dorper
4	243	Merino/Maternal/Terminal/Dorper	241	Merino/Maternal/Terminal
Total	929 (slaughtered)		883 (slaughtered)	

Methane. Post-weaning gas production (CH_4, CO_2 and O_2) using Portable Accumulation Chambers (PACs) was captured from all lambs during early post-weaning in December 2022 (n= 929) and 2023 (n=899). A second methane measurement was completed prior to slaughter for kill groups 2-4 for both cohorts. In both years, pasture had senesced, therefore all lambs were supplemented with pellets and oaten hay in 2022, and oaten hay plus grain (oat:lupin; 70:30%) in 2023. Dorper lambs were managed separately to Merino/Maternal/Terminal lambs. On the day of methane, both flocks were drafted into groups (n=16). Time off-feed ranged between 1-5 hours. Methane measurements were completed over 6-11 runs on any day. Sheep were moved into a sunken race filled with approximately 25mm of water and a PAC was lowered over each sheep using marine ropes and pulleys. PAC and ambient temperature, pressure and humidity were recorded at the start and end of each 45-minute run. CH_4, O_2 and CO_2 levels were recorded inside and outside the PACs every fifteen minutes (3 gas measurements per run). Gases were measured using an Eagle 2 gas analyser. Prior to each run, and between each 15-minute measuring interval, the Eagle 2 was tested against standards of known CH_4, O_2 and CO_2. All non-linear methane accumulation records were removed (up to 2% of records).

Body composition. Muscle and fat were measured twice via ultrasound at the C-site (Robinson et al. 1992) using a Sheep Genetics accredited scanner. They were first measured at early post-weaning age (Jan 2022 and 2023) and again immediately prior to slaughter.

Feed intake. All lambs were adapted to an *ad libitum* pellet diet over 14 days outside. The sheep were then stratified by weight (to reduce bullying) and randomised by sire into up to 20 indoor pens with 10-14 sheep per pen. All pens were weighed twice weekly. Daily feed intake measurements were recorded automatically for about half of each kill group in the facility (10 reading and 10 non-reading pens; total=758 lambs). Intake data was captured as individual meals. A cleaning algorithm removed meals with blank or not-present EID, where feed intake was 0 or negative and outlier meals (3 x SD from mean meal intake rate – to remove events involving cleaning of the feed trays). After cleaning, the data was summarised into individual daily intake for each sheep. All sheep with >40% coefficient of variation in daily intake were removed n=41 or 5% of records).

Residual Feed Intake (RFI). RFI was estimated using multiple linear regression. Average daily intake (ADI) was adjusted by fitting (1) mean metabolic mid weight; MMWT and (2) Average Daily Gain (ADG) as covariates.

(1) MMWT = the predicted mid weight during the feed intake test calculated via linear regression of the twice weekly weights throughout the intake test
(2) ADG = the slope of the linear regression used to calculate MMWT

The unexplained variation after fitting this model was the RFI. Each kill group was modelled separately with pen fitted as group. Date of birth, birth type and sex were added and dropped from all models as their effects were insignificant (excepting one model/kill group) in addition to MMWT and ADG. Residual Maximum Likelihood was used to test feed intake for significant sire effects for each cohort separately. Kill group, MMWT and ADG and sire were fitted as fixed effects (plus all significant two-way interactions) with dam and pen fitted as random effects. All non-significant terms were dropped from the final model(s).

RESULTS AND DISCUSSION

Differences in sire means for RFI were significant for the 2022 cohort (P<0.001; Figure 1). For this cohort 99 sires were represented with an average of 3.4 progeny per sire (range 2-7 progeny per sire). For the 2023 cohort there were 101 sires represented with an average of 3.0 progeny per sire (range 2-8 progeny per sire), sire differences were undetectable for this cohort. More important, sires from all breed types were represented at the extreme ends of RFI across both cohorts. Sires means for RFI (using only sires with at least 3 progeny per sire) varied from -170 ± 0.10 g/hd/day (n=10) to +180 ± 0.08 g/hd/day across all kill groups and cohorts. Using an estimated heritability of RFI for sheep of 0.1 (Cammack et al. 2005; Paganoni et al. 2017), this indicates potential genetic gains of 0.3% per year are possible through feed-intake testing under ad libitum feeding conditions pre-slaughter (assuming consistent selection pressure and a 4-year generation interval).

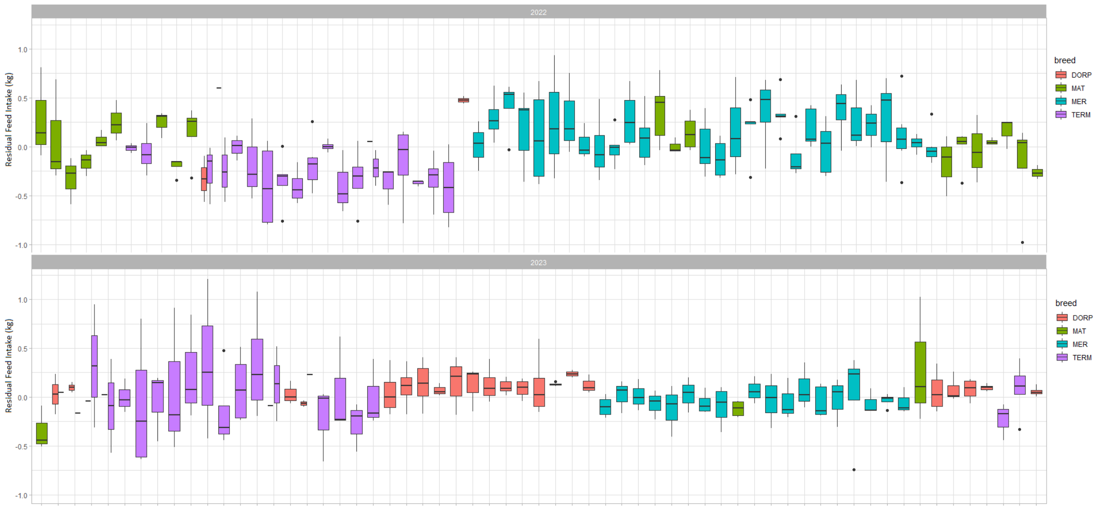

Figure 1. Sire predicted means for residual feed intake (kg) for the 2022-born (upper) and 2023-born (lower) lambs grouped by key breed types (Dorper = orange, Maternal = green, Merino = blue, Terminal = purple) from the MLA resource flock (only sires with >2 progeny shown).

MMWT varied from 47-58 kg and ADG pre-slaughter from 79-225g/hd/day and ADI varied between 1.4 and 1.9 kg/hd day between kill groups across cohorts.

MMWT and ADG explained 72-89% of the variation observed in ADI (Table 4), consistent or better than previous reports for sheep (Paganoni et al. 2014). MMWT had the greatest and most significant effect on ADI across most of the kill groups with consistent increase in intake of 60-70g for every 1kg increase in weight ($P<0.05$; Table 4). ADG had additional significant positive effects to MMWT for four of the six kill groups measured ($P<0.05$; Table 4). For every 1g/hd/day increase in ADG there were additional increases in ADI of 1.5-2g per day ($P<0.05$; Table 5). There were no significant effects of birth type or sex on ADI (beyond differences accounted for by MMWT). Age at had a small significant additional effect on ADI for one of the six kill groups measured (19g of additional ADI/day older at slaughter, $P<0.05$; Table 5). Body composition as measured by ultrasound scanning of muscle and fat pre-slaughter had no significant effects on ADI, neither did changes in muscle and/or fat between the post-weaning and pre-slaughter measurements. There were also no significant relationships detected between ADI and methane production measured via PACs pre-slaughter or the average of both PACs (pre-slaughter and post-weaning).

Table 4: Estimates of significant terms from the linear regression model for residual feed intake for the kill groups 2-4 of the 2022&2023-born lambs from the MLA resource flock at Katanning. The variation explained by the significant model terms appears in brackets (%VE).

Year, grp (%VE)	MMWT	ADG	Date of Birth
2022 2 (89%)	0.11 ± 0.004	n.s.	0.019 ± 0.005
2022 3 (72%)	0.07 ± 0.025	n.s.	n.s.
2022 4 (84%)	0.06 ± 0.022	1.52 ± 0.730	n.s.
2023 2 (89%)	n.s.	1.81 ± 0.840	n.s.
2023 3 (75%)	0.07 ± 0.026	2.03 ± 0.794	n.s.
2023 4 (77%)	0.06 ± 0.018	1.53 ± 0.804	n.s.

CONCLUSION

The findings of this study provide key preliminary insights into sire variation for feed intake and efficiency traits in Australian sheep. Initial findings indicate that genetic gains in residual feed intake, while small (0.3% per year) may be possible for permanent and cumulative efficiency gains in lamb finishing systems. Notably, over 75% of variation in daily feed intake is explained by weight and growth, with methane production and body composition, contributing minimally. This underscores the central role of weight and growth in driving feed-use efficiency, under *ad libitum* finishing systems. Importantly, sires across all major breed types exhibit extremes in residual feed efficiency, suggesting broad genetic variability that can be leveraged for selection.

ACKNOWLEDGEMENTS

Supported in part by Meat and Livestock Australia (MLA), project numbers L.GEN.2103 and L.GEN.1804. Ethics approval; Department of Primary Industries and Regional Development Western Australia (AEC 23-5-18). We also acknowledge all involved with data collection.

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8.2.2 B Paganoni, B Bolt, A Bowden, K Moore, C Macleay (2024). Feed intake for sheep fed *ad libitum* pellets under feedlot conditions can be estimated precisely in three weeks for most breed types. *Australian Association of Animal Science* V35 p48.

Decision: Oral Presentation

Feed intake for sheep fed *ad libitum* pellets under feedlot conditions can be estimated precisely in three weeks for most breed types (11427)

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Introduction Animals that eat less but produce more are more efficient and profitable. Identifying and breeding more efficient animals requires the precise measurement of feed intake. In the standard beef cattle model, 35 days of measuring feed intake is the minimum time required for sufficient precision for young growing heifers (Archer *et al.* 1997). For sheep, Merinos have a stable intake trait after 21 days, irrespective of age (Macleay *et al.* 2014). We tested whether 21 days could establish a precise measurement of feed intake for a group of sheep of mixed sire and dam breeds.

Material and methods We measured feed intake between Feb and May 2023 in sheep (n=297) from Merino, Maternal, Terminal and Dorper sires from the genetic resource flock (Van der Werf et al. 2010). The sheep were measured in three mixed sire groups (n=84, n=106, n=107) between 6-10 months of age for 26-30 days. The sheep were randomised by sire in pens of up to 14 and fed pellets ad libitum (11.9 MJ/kg dry matter and 13.1% protein), with individual intake recorded automatically. Daily intake was calculated by summing the total feed eaten over each day. We compared the variance of intake measured over 1, 2, 3, to 26-30 days. We also estimated the correlations of feed intake measured of different time periods to feed intake measured over 26-30 days.

Results Variation in daily feed intake became stable in less than 30 days (Figure 1), and correlations between 21 and 30 day test periods were around 0.95 (Figure 2). Weaners from Terminal sire types ate the most (average 2.0 kg/hd/day) and Merino sire types ate the least (1.7 kg/hd/day) over the 26-30 day measurement period. Variation in feed intake measurements was higher for our post-weaning study (~0.34) than for Macleay et al. 2014 (0.22). This is likely due to more variation in size of our sheep and reflected by our higher average comparative intake for Merinos (1.7 kg vs 1.5 kg for Macleay et al. 2014).

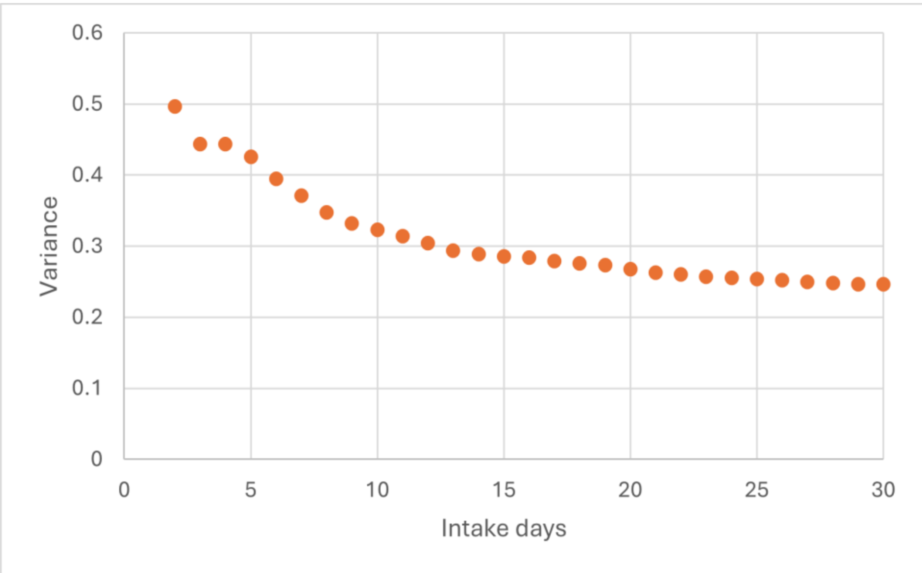

Figure 1. Variance of average daily intake plotted against the number of days measured for three groups of sheep of various breeds measured at post-weaning age between Feb and May 2023.

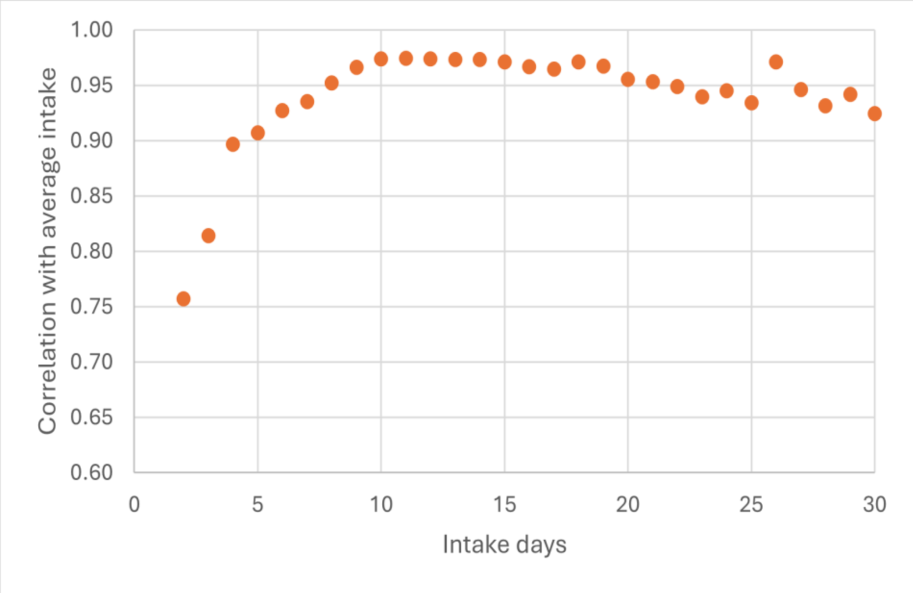

Figure 2. Correlation between feed intake measured over 26-30 days with feed intake measured between 1 and 26-30 days for three age groups.

Conclusion and implications Measuring feed intake for 21 days can establish a precise measurement of feed intake for a group of weaners of mixed sire and dam breeds.

Acknowledgements Supported by Meat and Livestock Australia (MLA), project number L.GEN.2103. Ethics approval; DPIRD's Animal Ethics Committee (AEC 20-5-13).

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8.3 SOP Measuring feed intake and feed efficiency of sheep housed in group pens.

Animal description

Sheep of any breed and sex. Recommended minimum age is 4 months, and ewes greater than 100 days pregnant require specific AEC approval.

Objective

To accurately measure feed intake and/or feed efficiency from individual sheep housed in group pens indoors.

Details of procedure

Pre-procedure preparation

Review SDS, OSH risk assessment and related SOPs and policies – refer to OSH section in this SOP for more information.

Review biosecurity procedures for property where this procedure is to be performed. This SOP only provides a brief overview.

Obtain training for major equipment including feed delivery system and electronic data capture system.

Order feed

Calibrate and test feed units – details provided in "Description of technique"

Equipment required

Feed intake and feed efficiency measurements collected from group housed sheep require a purpose-built facility, such as the Sheep Feed Intake Facility at the Katanning Research Station.



Additional equipment includes;

- Test weights x 10 ranging from 10-500g with assigned EID

- 1 or 2kg calibration weight
- Autodrafter and 20kg test weight
- Autovaccinator for administration of routing health treatments
- Drenching kit
- Urine pots or zip lock bags (for WEC)

Description of technique

Adaptation to diet

This phase focuses on adapting the sheep to the diet. The adaptation protocol will be dependent on whether this is a novel diet or continuation of current diet. Ad lib hay is provided during this phase.

1. Novel diet – Sheep are to be adapted to the new diet over a period of 2 weeks and will occur under feedlot conditions. Introduction to the pellet starts at 100g/hd increasing by 100g/hd/day until ad lib at a minimum of 1.4kg/day. The ration is feed daily to ensure minimal chance of acidosis.
2. Continuation of current diet – Sheep continuing their current diet will only need to be in the feedlot for as long as it takes to increase their daily ration to ad lib (~1.4kg/hd). Sheep already receiving ad lib may enter the shed directly.

During adaption, sheep will be weighed and condition scored as they enter the feedlot and weighed twice a week to monitor health via growth rates. Additionally, sheep are to be given routine health treatments to minimise incidence of common and preventable health issues including polio encephalomalacia (thiamine deficiency).

Based on recommendations from the National procedures and guidelines for intensive sheep and lamb systems (Dickson and Jolly, 2011), the routine health treatments are;

a) Inject all sheep with:
    - <u>2 mL B1</u> (Thiamine hydrochloride 125mg/mL, Ceva Animal Health Pty Ltd, Glenorie, NSW Australia)
    - <u>1-2 mL Vit ADE</u> (vitamin A (retinol palmitate) 500,000IU/ml, vitamin D3 (cholecalciferol) 50,000IU/ml, vitamin E (dl-α-tocopheryl acetate) 50IU/ml, Bomac Animal Health Pty Ltd, Hornsby NSW, Australia). *Exception: if the measurement period is less than 1 month, Vit ADE is optional.*

b) Drench sheep with 5mL Vitamin E (50% w/v solution of d, l alpha-Tocopherol acetate 66 IU/g). *Exception: If the sheep have been off green feed for less than 2 months, or, the diet is formulated with at least 30ppm Vit E, then Vit E drench is not required.*

c) Collect minimum of 10 faecal samples and submit for intestinal worm egg count WEC. Based on results – drench with appropriate anthelminthic if required. *Exception: if the sheep are going to slaughter after completion of measurement, a WEC is not required, and all sheep can be drenched (note WHP of drench).*

Adaptation to facility and feeding system

Once the adaptation to diet phase is complete, sheep may enter the shed to begin the adaptation to facility, or ‘training’ phase. This phase is a minimum of 3 days and allows the sheep to acclimate to the shed environment and to settle in with their penmates. During this phase sheep will have unrestricted access to the feed via an automated feeding system.

Upon entering the shed, the sheep should be weighed, conditioned scored, and drafted into groups of up to 13 individuals per pen (based on current floor space of pens at the Sheep Feed Intake Facility at KRS, stocking density may be increased with AEC approval). The lead-in chutes to the feed units will be opened to allow sheep unrestricted access. The chutes will be open for a minimum of 3 days to ensure sheep are comfortable feeding from the feed unit and other objects in the shed, establish pecking orders and get accustomed to staff entering and walking through the Facility.

Sheep assigned to groups should be similar in liveweight to minimise bullying and allows the optimal setup of the lead-in chute to minimise risk of entrapment.

Data collection
After 3 days of training, the lead-in chutes will be closed to restrict access to the feed unit so only one sheep can access the feed at a time. During the measurement period sheep are weighed twice weekly.

Feed intake is recorded by an automated feeding system. As the sheep enters the lead-in chute, the EID of that sheep is recorded, and the weight of feed in the feed tray. Once the sheep leaves the lead-in chute, an exclusion flap on the unit closes, re-weighs the feed left in the tray and tops up the tray if needed. After the weight is recorded and topped up, the exclusion flap reopens to allow the next sheep to access the feed.

Feed intake data should be measured over a minimum period of 21 full days (Macleay *et al*, 2016). To measure feed efficiency a longer test length is required. The current recommendation is 6 weeks (Amarilho-Silveira et al., 2022). This additional time is required to achieve a stabilisation of growth rate.

If sheep have already been through the Facility, training is not necessary.

An example of a feed intake timeline is described in Table 1.

Table 1. Example of feed intake timeline. To measure feed efficiency, the data collection phase would continue for an additional 3 weeks.

1	-17	Adaption to feed	Sheep weighed and condition scored into plots, administer routine health treatments	100
1	-16	Adaption to feed		200
1	-15	Adaption to feed		300
1	-14	Adaption to feed	Sheep weighed	400
1	-13	Adaption to feed		500
1	-12	Adaption to feed		600
1	-11	Adaption to feed		700
2	-10	Adaption to feed	Sheep weighed	800
2	-9	Adaption to feed		900
2	-8	Adaption to feed		1000
2	-7	Adaption to feed		1100
2	-6	Adaption to feed	Sheep weighed	1200
2	-5	Adaption to feed		1300
2	-4	Adaption to feed	Feed unit calibration and test weights	1400
3	-3	Adaption to Facility	Sheep weighed and condition scored into Facility pens, lead-in chutes open	*ad lib*
3	-2	Adaption to Facility		*ad lib*

3	-1	Adaption to Facility		*ad lib*
3	0		Sheep weighed, feed unit test weights, lead-in chutes closed	*ad lib*
3	1	Data Collection		*ad lib*
3	2	Data Collection		*ad lib*
3	3	Data Collection		*ad lib*
4	4	Data Collection	Sheep weighed	*ad lib*
4	5	Data Collection		*ad lib*
4	6	Data Collection		*ad lib*
4	7	Data Collection	Sheep weighed, feed unit test weights	*ad lib*
4	8	Data Collection		*ad lib*
4	9	Data Collection		*ad lib*
4	10	Data Collection		*ad lib*
5	11	Data Collection	Sheep weighed	*ad lib*
5	12	Data Collection		*ad lib*
5	13	Data Collection		*ad lib*
5	14	Data Collection	Sheep weighed, feed unit test weights	*ad lib*
5	15	Data Collection		*ad lib*
5	16	Data Collection		*ad lib*
5	17	Data Collection		*ad lib*
6	18	Data Collection	Sheep weighed	*ad lib*
6	19	Data Collection		*ad lib*
6	20	Data Collection		*ad lib*
6	21	Data Collection		*ad lib*
6	22		Sheep weighed, condition scored, and finish/leave Facility	*ad lib*

Calibrate and test feed units

To assess and ensure the accuracy of the feed intake data collected, a calibration and testing of load cell accuracy of the feed units are performed prior and during feed intake/efficiency measurement.

1. Calibration check – Prior to measurement, each unit is tested with a 1 or 2kg test weight to ensure the weight reading is correct. This is performed with no feed in the feed tray. If the weight is not correct, perform a calibration.
2. Test weight assessment – Prior to measurement, after calibration, and at regular intervals, ideally weekly, during measurement, the accuracy of the weight readings is tested using known weights and EIDs to capture the data (for record keeping and future analysis). This method is designed to mimic a sheep meal. 10 test weights ranging from 10g-500g are placed in the feed tray and are extracted individually using an assigned EID (Figure 1). The data capture system records the test weight removal as a meal, which is compared to the known weight to provide an estimate of error and identifies individual pens that may have recording issues. Any issues are addressed immediately.

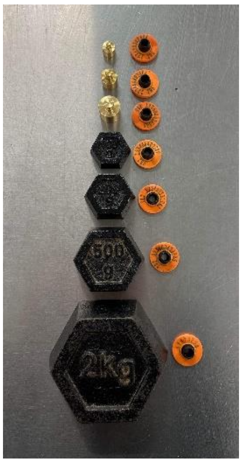

Figure 1: Feed Unit calibration weights and EID tags.

Qualifications, experience, skills or training necessary to perform this procedure

Be trained in operational safety associated with sheep work including animal ethics training, OSH training, and first aid training.

Attend an approved animal handling technique course or be trained in handling sheep by a competent operator.

Be deemed competent in the technique by training and supervision by a trained and experienced operator.

Record competency with the AEC.

Have an understanding of zoonoses (animal-human diseases) and the causes, DPIRD policy 22.22.01. Refer to OSH section for more information.

Drugs, chemicals or biological agents used (dose, route of administration, etc.)

None

Effects of drugs, chemicals or biological agents

None

Effects on well-being of animals (include critical limits and precautions)

Failure to adapt to diet

The two-week adaption is usually adequate to allow rumen adaption, however, in some instances, sheep who are shy feeders may not get the appropriate level of rumen adaption during the two week period. To minimise this risk, it is recommended that mob size during this period be limited to no more than 100 individuals.

Mild scouring may be observed during the adaption to diet phase, which usually clears up as the sheep adapt. Ad lib hay is provided to maintain rumen health during this phase. The worm egg count will also indicate if the issue could be worm related – if a worm drench is required, ensure that is completed immediately.

- If a high proportion (>25% of sheep) of the mob are observed actively scouring, do not increase the ration, but maintain, or lower the ration, until the scouring has cleared. Then the daily ration increase can be re-introduced.
- If the scouring does not improve within a couple of days consult a veterinarian.
- If at any time the scouring is severe and causing ill health, remove the feed, or the individual, and consult a veterinarian.

Failure to adapt to Facility

Sheep in intensive housing generally adapt very well. It is recommended to introduce the sheep to the Facility as early in the day as possible to allow the sheep more time under observation for adjustment of lead-in chute if required.

- Those sheep which have not adapted well will be identified by liveweight or condition score loss, or by visual observation of bullying or poor demeanour.
- Any sheep identified as poorly or non-adapted will be checked for ill health and removed from its pen. If no signs of ill health are found, place the sheep into a new pen with fewer and/or smaller sheep. In most cases, this resolves this issue.
- If continued weight or condition score loss is observed, or if demeanour doesn't improve, the sheep will be removed from the group pen and fed individually, or removed from the Shed, and continued to be monitored.
- If improvements are not observed, consult a veterinarian.

Entrapment

There is potential for sheep to become stuck in the lead-in chute or in the feed unit. In order to minimise this, as well as any potential injury risk, there are 3 key elements incorporated into the design that are required to ensure sheep do not become trapped (Figure 2, Figure 3).

1. Head bale
2. Angled lead-in chute
3. Back bar

It is important that all 3 elements are set up to meet the specific needs for the size of sheep within each pen. Sheep must be observed closely for several hours after being introduced to the pens, and after the lead-in chutes are narrowed, so adjustments can be made if required.

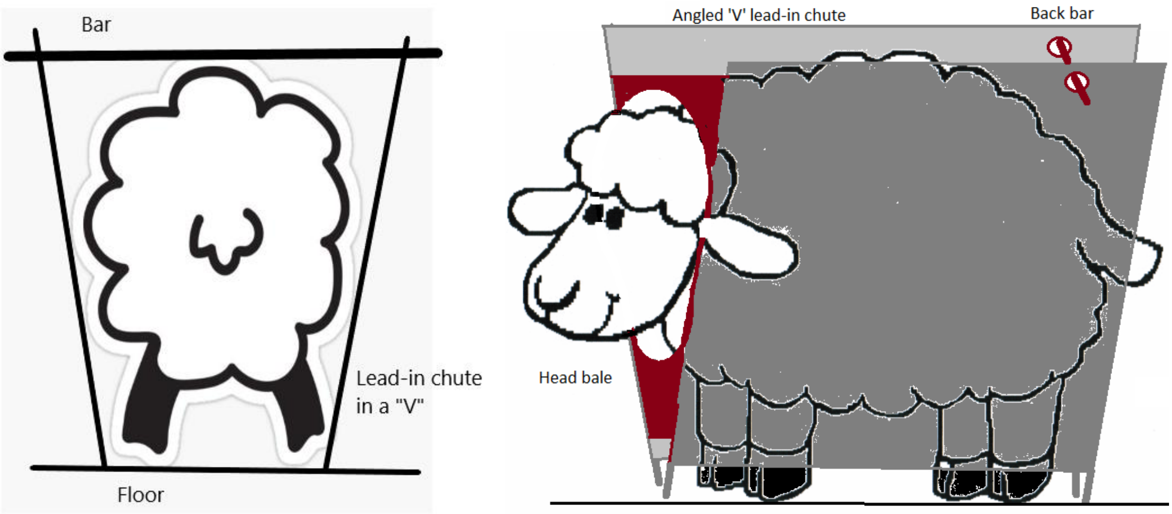

Figure 2. Illustration demonstrating V-shape of lead-in chute, the back bar, and the head bale at the front of the chute, indicating ideal set-up and placement.

Head Bale

The head bale at the front of the lead-in chute prevents sheep from getting too close to the feed unit, and performs two important functions;

a. to protect the feed unit from damage caused be the sheep, for example, chewing cables,
b. to keep the sheep at a safe distance from the feed unit to prevent them getting caught in any of its components.

The head bale has a keyhole where the sheep must put their head through to reach the feed tray. The lowest point of the keyhole is at the height of the feed tray to allow maximum reach. It is wider at the top to provide an inviting and open space to put their head through, and narrower at the base to prevent shoulders from passing through.

Lead-in Chute

The lead-in chute is fully adjustable and can be customised for each pen based on the size of the sheep. If it is within the scope of the project, grouping sheep by liveweight will help to minimise the range of sizes in each pen and allow the setup to be more precise.

The lead-in chute should be set to the shortest widest sheep in the pen to maintain sheep in single file, and in a V-shape so it is narrower at the ground (Figure 2, Figure 3). This prevents sheep from getting stuck, or from sitting or falling in the chute. The lead-in chutes may need adjusting over time as liveweight increases.

Back Bar

A bar placed horizontally above and behind the sheep in the chute prevents other sheep from jumping on and over the sheep in the lead-in chute. Placement of the bar should be at the height of the tallest sheep and at tail length from the front of the chute when a sheep is eating.

Figure 3. Photo of actual lead-in chute and head bale at the Sheep Feed Intake Facility.

Long-term confinement

Group pens provide sheep with social interaction and reduce the stress of long-term confinement.

Appropriate stocking density is important to ensure the behavioural needs of the sheep are met. The recommended stocking density for animals used for scientific purposes is 1.5m^2 per sheep of floor space to allow space to rest, move away from others and express normal behaviour (Guidelines for the Housing of Sheep in Scientific Institutions, 2010). Increases to stocking density require AEC approval.

Enrichment such as broom heads for scratching provide increased behavioural diversity, reduce the frequency if abnormal behaviour and provides and outlet for physical activity and choice over how they spend their time. Enrichment should be provided were practicable.

Injury

If an animal is injured, adequate treatment must be given, or it must immediately be humanely destroyed if the injury is serious.

Ill health

If an animal is found to be flyblown or showing other signs of ill health, it must be treated appropriately.

Provision of pain relief

Pain relief is not required for this procedure.

Care of animals after procedure

Sheep do not need after care. Once they have completed their measurement, they can be removed from the Facility and resume regular activities.

Contra-indications for use of procedure

It is not recommended to measure sheep under 3 months of age and under 25kg. To measure sheep younger or lighter, seek specific AEC approval.

Do not measure sheep with signs of illness or abnormal behaviour.

Do not measure ewes within six weeks of the start of lambing (where the start of lambing is defined as 5 months after the rams have gone in, or the date of artificial insemination) except with specific AEC approval.

Do not yard ewes and lambs for at least two weeks after marking except with specific AEC approval.

Workplace Safety and Health (WHS)

Protective Personal Equipment (PPE)

Refer to Related Policies and Documents section for AS/NZS PPE standards

- Safety footwear such as leather work boots. Steel-caps not required.
- Coveralls or long sleeved shirt and pants.
- Hat and sunscreen if working outside.

Safety Data Sheets (SDS)

- There are no chemicals used in this procedure.

Zoonoses

- Zoonoses include Q fever, campylobacter, toxoplasmosis, salmonella, acariasis (rash caused by mites), leptospirosis, listeriosis, orf (scabby mouth) and ringworm.
- Operators are to be aware of symptoms of zoonotic diseases transmissible from sheep and wear PPE as described. For staff undertaking work at DPIRD research facilities, this information is provided in staff inductions.
- Operators either require a Q fever vaccination or a record of immunity or have declared that they have abstained from the vaccination by completing the Non-Consent form, as per DPIRD Guidelines.

Safe Animal Restraint

- At least two people must be present for animal handling activities.
- Ensure the animal handling facilities are adequate to perform the measurements safely with effective gates, rails and raceways.

Other procedure specific information

None

Risk Assessment

Risk assessment performed using DPIRD risk matrix

Potential Harm	Harm could occur to operators from biological, physical, chemical and ergonomic hazards including injuries caused by working with sheep, exposure to sun and exposure to zoonoses.

	The control measures described above have been put in place to minimise hazards to reduce risk to operators
Probability	Probability rating: E – Rare – Practically impossible, but may occur in exceptional circumstances
Consequences	Consequence rating: 1 – Incident only
Risk Rating	**Low**

Related Policies and Documents

The following policies are currently being reviewed by the WHS team and will be made available on the DPIRD Intranet in due course. The links below are to legacy documents on AgWeb and may be used as a guide, however should also be used with caution as they may not be up to current standards with regards to legislation or staff obligations.

Contact WHS directly for further information – WHS@dpird.wa.gov.au.

Personal Protective Equipment #22.12.01

Zoonoses #22.22.01

Manual Tasks #22.10.01

Work In Remote Areas Policy #22.24.01

Driving Policy #22.08.01

Communication Safety Policy #22.27.01

75.02 - Occupational Safety Health (OSH) Management Policy

AS/NZS 4501.1:2008 Occupational protective clothing - Guidelines on the selection, use, care and maintenance of protective clothing

AS/NZS 4501.2:2006 Occupational protective clothing - General requirements

AS/NZS 4399:1996 Sun protective clothing - Evaluation and classification

ChemAlert

Biosecurity

If performing procedure at usual place of work

This applies to DPIRD Research Facilities.

- Follow biosecurity protocols for each Research Facility.

If performing procedure at alternative place of work, or for employees who have recently visited sheep properties

This applies to sampling at private properties or Research Facilities that are not the operators usual place of work, or for employees who have recently worked on sheep properties.

- Use freshly laundered clothing, clean boots/shoes, and gloves if necessary.
- Remove all rubbish and dispose of appropriately.
- Ensure boot or shoe treads are scrubbed and all particulate material removed either on site, or take a change of footwear and clean on return to base.
- Don't use private vehicles in the paddock.

References

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Animal Research Review Panel (2010) Guidelines for the Housing of Sheep in Scientific Institutions (animalethics.org.au).

Amarilho-Silveira, F., de Barbieri, I., Cobuci, J. A., Balconi, C. M., de Ferreira, G. F., & Ciappesoni, G. (2022). Residual feed intake for Australian Merino sheep estimated in less than 42 days of trial. *Livestock Science*, *258*, 104889. https://doi.org/10.1016/j.livsci.2022.104889

Dickson H and Jolly S (2011) National procedures and guidelines for intensive sheep and lamb feeding systems. https://www.mla.com.au/globalassets/mla-corporate/extensions-training-and-tools/documents/nationalproceduresandguidelineslambfinishing.pdf