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Citation of papers
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Quantifying the effect of grilling and roasting on the eating quality of lamb leg muscles

Hussein Al Moadhen[A,B], *Jarrod C. Lees*[A] *and Peter McGilchrist*[A]

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Lamb eating quality was measured using consumers to develop a cut by cook method eating quality program for sheepmeat. The current protocol for cooking and serving roast lamb legs does not allow for the differentiation of muscles. Thus, there is no comparison of grilled and roasted lamb leg muscles. Previous work conducted in beef has shown that there is a difference in consumer sensory scores for grilled and roasted *m. semimembranosus* (Watson *et al.* 2008). This differentiation has allowed the beef industry to predict the eating quality of individual cuts, for each prescribed cooking method. This study aimed to quantify the effect of cooking method on the eating quality of three different muscles: *m.semimembranosus* (topside); *m.biceps femoris* (outside flat); and *m.rectus femoris, vastus lateralis* and *vastus intermedius* (knuckle). It was hypothesised that the outside flat, topside and knuckle will have different consumer eating quality when cooked using grill and roast.

Eating quality samples were collected from the 2018 drop of information nucleus flock lambs at the University of New England as part of larger study. Sixty carcasses were fabricated into consumer sensory samples for the grill and roast cook methods. The outside, topside and knuckle from one leg were portioned into grill samples, while the opposite leg was portioned into a single roast consisting of topside and outside, with the knuckle removed. Leg (left/right) was rotated between carcasses for grill and roast cook methods. Sensory testing was completed using untrained consumer sensory panels who scored lamb for tenderness (T), juiciness (J), flavour (F) and overall liking (OL) (Watson *et al.* 2008). Ten consumers tested each sample. Data were analysed using a linear model in R (R Core Team 2020), with muscle and cook method as fixed effects, and the interaction between muscle and cook method, to estimate the variance in eating quality score.

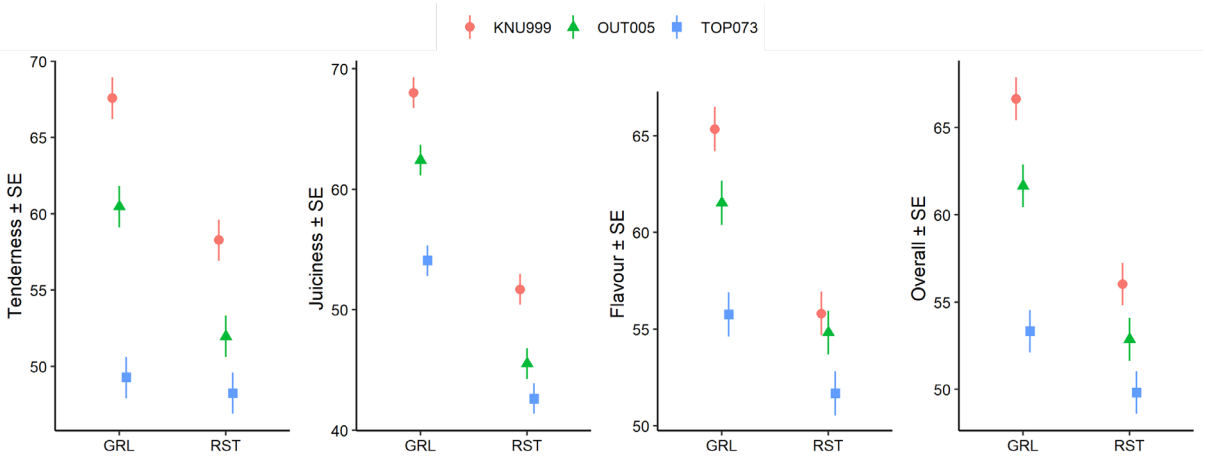

Fig. 1. Estimated marginal means sensory score ± Se for tenderness (T), juiciness (J), flavour (F) and overall liking (OL) from two different cooking methods roast (RST) and grill (GRL) for three different cuts (knuckle = KNU999, outside flat = OUT005 and topside = TOP073).

All muscles had higher scores for T, J, F and OL when cooked as grill in contrast with roast ($P < 0.01$), but topside was not different for T between grill and roast. Knuckle scored higher than outside and topside for T, J, F and OL when cooked as a grill and roast ($P < 0.05$) other than F of the roast. Knuckle and outside scored higher for J as a grill (68 ± 1.4 and 62 ± 1.3 respectively) and roast (51 ± 1.3 and 46 ± 1.3 respectively) than topside grill and roast (54 ± 1.4 and 43 ± 1.3 respectively).

These findings demonstrate the importance of cooking method and the impact different muscles have on the sensory scores of lamb leg muscles, supporting the hypothesis. Cooking method directly affects consumer sensory score for lamb leg muscles but this largely contrasts the relationship seen in beef where roasts typically score higher than grills. The differences between muscles might be caused by the collagen content of the muscles or other intrinsic factors such as the structure of the myofibrils, muscle fibre type and connective tissue. These factors can impact cooking method and sensory scores (Bassam *et al*. 2022). Further research is required to determine the influence of cooking methods on retail cuts and individual muscles and understand the characteristics of the meat that is impacted by cooking methods.

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Prevalence of *Ureaplasma diversum* in induction cohort animals sampled at two time-points (day 0 and day 14) and hospital pen animals from a Southern NSW feedlot

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Bovine respiratory disease (BRD) is the most common disease of feedlot cattle worldwide. It is a complex disease and many bacterial and viral agents have been implicated in its aetiology. *Ureaplasma diversum* is commonly associated with other bovine ailments, such as abortion and infertility, and more recently has been implicated in the pathogenesis of BRD (Szacawa *et al.* 2016). However, the involvement of *U. diversum* in BRD as a non-commensal microorganism is not well understood. To better understand the prevalence of this organism in the Australian feedlot system, we compared the prevalence of *U. diversum* in feedlot cattle at three stages within the feedlot system using quantitative PCR.

Nasal swabs were collected from an induction cohort of animals in a Southern NSW commercial feedlot at induction (day 0) and again after 2 weeks on feed (day 14). Cattle located in the hospital pen on the same collection dates were also sampled. Two hundred and sixteen nasal swabs were collected from the induction cohort and 34 nasal swabs from hospital pen animals for comparison. These collections occurred during the low-risk BRD period between October and November 2020 (Barnes *et al.* 2015), with approval from Charles Sturt University (ACEC Protocol A18070). The swabs were stored in viral transport fluid (VTF, Edwards Group Pty Ltd, Australia) and processed for qPCR analysis using a direct heat extraction method. To determine the presence of *U. diversum,* PCR was performed using published primer sequences (Kishimoto *et al.* 2017) and PerfeCTa® SYBR® Green FastMix® (Quanta BioSciences, USA) with minor modifications. Any samples with a PCR cycle threshold (Cq) value of less than 40 was considered as having detectable *U. diversum*.

There was a low prevalence of *U. diversum* detected in cattle at induction (day 0 n = 15, day 14 n = 21) and no significant difference between prevalence at day 0 and day 14 (Fisher's exact test, P = 0.3844; Fig. 1A). Of the 216 induction cohort animals sampled, 3 had detectable *U. diversum* at both day 0 and day 14 collections. The detection rate of *U. diversum* was significantly higher (61% ± 15) in animals sampled from the hospital pen when compared to that of the induction cohort (P < 0.001; Fig. 1A). In addition, *U. diversum* was detectable equally in the 20 hospital pen animals whether treated for BRD or for other ailments (Fig. 1B).

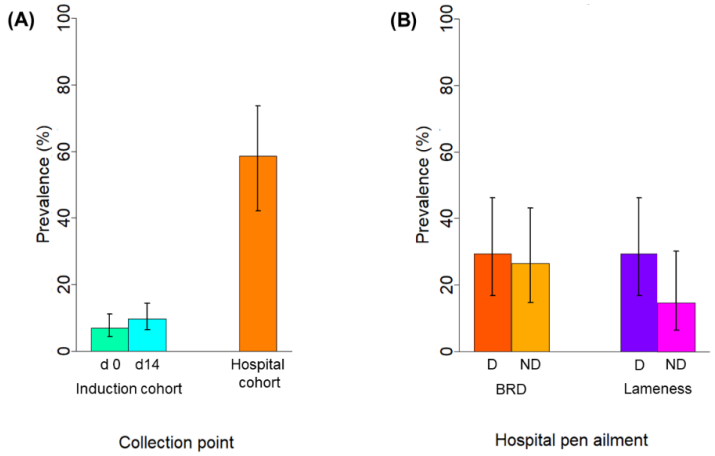

Fig. 1. Prevalence (+/- CI) of *U. diversum* in nasal swabs collected during low-risk period for bovine respiratory disease; (A) comparison between induction cohort animals at two time-points (day 0 (d 0) and day 14 (d 14), n = 216) and hospital pen animals (n = 34), (B) comparison between detectable (D) and not-detectable (ND) within the hospital cohort (n = 34) dependent on disease; BRD (detectable = 10, not-detectable = 9), lameness (detectable = 10, not-detectable = 5).

This study is the first to report on the detection of *U. diversum* from nasal swabs in Australian feedlot cattle. While *U. diversum* was detected at a significantly higher rate in cattle from the hospital pen than those sampled at induction, its prevalence was similar regardless of the hospitalisation ailment. These findings suggest that *U. diversum* may be contributing to disease in feedlot cattle although the contribution to BRD is currently unknown.

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Grazing management targets for improved pasture intake and utilisation

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Pasture intake (kg DM/animal.day) and utilisation (kg DM/ha.season) are factors driving the productivity and profitability of grazing systems. These factors are determined by grazing management targets (GMT) such as leaf stage, pasture utilisation per grazing and pasture residue management. Recent studies found that beef (Benvenutti *et al.* 2015) and dairy (Ison *et al.* 2019) cattle achieve high levels of pasture intake only when grazing the top leafy stratum (TLS) of pastures. Pasture intake started to decline when a small proportion of the TLS was left ungrazed only around the faecal patches. These findings led to the development of a new grazing management strategy called PUP (proportion of un-grazed pasture) grazing. To achieve high pasture intake the grazing intensity of PUP grazing is less than traditionally recommended. The target pasture utilisation per grazing of the PUP strategy is 100 % of the TLS mass excluding faecal patches for all pasture species. Instead, the traditional target utilisation is 80 % and 66 % of the pasture mass for annual ryegrass (DPI 2022) and kikuyu (Fulkerson *et al.* 1997) respectively. Also, recent plot studies found that less intense and more frequent defoliations resulted in greater pasture utilisation per season of the TLS in comparison to the more intense and less frequent defoliations that are traditionally recommended. These findings resulted in additional GMT for the PUP strategy for maximum utilisation per season. The target leaf stage for PUP grazing is 2 and 3.5 fully expanded leaves for annual ryegrass and kikuyu respectively. In contrast, the traditional recommendations for annual ryegrass and kikuyu are 2.5 to 3 (DPI 2022) and 4.5 (Fulkerson *et al.* 1997) leaves respectively. In addition, the PUP strategy includes maintaining the pastures residues at 10 cm using mechanical means or non-lactating animals for both pasture species. In contrast, it is traditionally recommended to regularly reduce the pasture residues down to 5 cm for annual ryegrass (DPI 2022) and kikuyu (Fulkerson *et al.* 1997) respectively. These grazing strategies have not been compared before.

This demonstration study was conducted at Gatton Research Dairy on annual ryegrass and kikuyu pastures grazed by dairy heifers during two growing seasons for each pasture species from 2019 to 2021. Heifers were randomly allocated to two pasture strips that were managed according to either the PUP or the traditional GMT. The number of heifers used and the amount of pasture offered per day was calculated based on the target pasture utilisation. Pasture intake and utilisation were measured using the double sampling method described by Ison *et al.* 2019. All data were statistically analysed with Genstat using analysis of variance. Growing seasons were used as replicates in the ANOVA analyses.

Despite the high grazing pressure, the heifers in the traditional treatment decreased pasture intake instead of grazing the pastures down to the target pasture utilisation (Table 1). Therefore, pasture intake was 61% and 53% greater for the PUP strategy for ryegrass and kikuyu respectively. The pasture utilisation per grazing was similar between grazing strategies for both pasture species. However, since the rotation length was longer for the traditional treatment the number of grazings per season was greater for the PUP strategy in both species. Consequently, the utilisation per season was 36 and 63% greater for the PUP strategy for ryegrass and kikuyu respectively. These results showed the potential of the PUP strategy to improve productivity and profitability of grazing systems, which should be quantified in future studies

Table 1. Results for the traditional and PUP grazing treatments[A]

	Annual ryegrass		Kikuyu		SEM	*P*-value
	Traditional	PUP	Traditional	PUP		
Pasture mass (kg DM/ha)	1779	1767	1682	1867	36	0.138
Pre-grazing pasture height (cm)	26.7^{b}	24.6^{ab}	25.5^{b}	21.7^{a}	0.6	0.040
Post-grazing pasture height (cm)	11.7^{a}	11.2^{a}	15.1^{b}	12.1^{a}	0.4	0.048
Pasture utilisation per grazing (kg DM/ha)	1112^{b}	1046^{b}	579^{a}	601^{a}	37	0.608
Pasture utilisation per season (kg DM/ha)	6107^{ab}	8326^{b}	4002^{a}	6511^{ab}	425	0.031
Pasture utilisation per day (kg DM/ha)	40.7^{b}	56.2^{c}	28.9^{a}	49.7^{c}	1.2	0.005
Pasture intake (kg DM/heifer.day)	5.7^{ab}	9.2^{b}	4.4^{a}	6.7^{ab}	0.8	0.062

[A]*P* values for grazing treatments. Within rows, means with a common superscript are not significantly different ($P < 0.05$).

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An evaluation of an individual cattle management model for use in Australian feedlots

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Predicting the optimal endpoint of beef cattle is key to improve both productivity and profitability in feedlots. This requires accurate predictions of animal growth and their body composition over time which could greatly vary between breeds, diet and nutrition, and environmental factors. Prediction models such as the Cattle Value Discovery System (CVDS) predicts economic and carcase endpoints using user-input data including live animal, carcase measurements, and environmental factors (Tedeschi *et al*. 2004). The study aimed to evaluate the CVDS model to predict performance and carcase outcomes of Australian feedlot steers under commercial conditions. It was hypothesised that (a) the model can predict animal growth and final body weight with medium to high accuracy, and (b) observed and modelled growth, final body weight, empty body fat (EBF) and carcase traits differ among cattle breeds.

Feedlot and abattoir data consisting of 210 steers from the Riverina region of NSW (Australia) were used for analysis in the present study. Steers ranged from 12 to 36 months of age, with breeds grouped into British (n = 119), British cross (n = 30), European (n = 47) and Bos *indicus* cross (n = 14). Steers were fed for 113 days, incrementally transitioning from a starter to a finisher diet over 21 days. Variables measured at the feedlot, abattoir and predicted by the model were analysed in RStudio (RStudio Inc., Boston, MA, USA; R Core Team 2021). Differences between breeds for predicted and observed variables were analysed using Pearon's correlation analysis, and a linear regression model, with the breed group as independent fixed effect and the remaining variables as dependent.

The final shrunk body weight (SBW) from both the model and the feedlot, along with the feedlot average daily gain (ADG) did not differ among breeds ($P > 0.05$). However, predicted ADG and dry matter intake as a percentage of body weight (DMI%) were greater for European steers in comparison with British steers ($P < 0.05$). Initial EBF ($P < 0.05$), carcase fat ($P < 0.01$), EBF predicted from observed carcase traits ($P < 0.01$) and final EBF at day 113 ($P < 0.05$) were lower for European than British steers. There were obtained significant and positive Pearson's correlation coefficients between predicted and observed ADG (r = 0.74; $P < 0.001$) and final SBW (r = 0.59; $P < 0.001$).

Table 1. Model-predicted outcomes by the CVDS model for different groups of breeds of feedlot cattle[A]

Variable	B. *indicus* cross	British	British cross	European	*P*-value
Feedlot Final SBW (kg)	678 ± 15.5	683 ± 5.3	679 ± 10.6	680 ± 8.5	0.969
Feedlot ADG (kg/d)	2.27 ± 0.166	2.32 ± 0.057	2.28 ± 0.114	2.50 ± 0.091	0.311
Model predicted variables					
Predicted Final SBW (kg)	727 ± 11.5	729 ± 4.3	743 ± 7.9	724 ± 6.3	0.292
Predicted ADG (kg/d)	2.61 ± 0.077^{xy}	2.65 ± 0.026^{y}	2.75 ± 0.052^{xy}	2.79 ± 0.042^{x}	0.014
DMI (kg/d)	11.8 ± 0.20	11.9 ± 0.07	12.2 ± 0.14	12.1 ± 0.11	0.097
DMI (% BW)	2.09 ± 0.040^{xy}	2.11 ± 0.014^{y}	2.13 ± 0.027^{xy}	2.20 ± 0.022^{x}	0.004
Initial EBF (%)	20.7 ± 0.45^{xy}	20.6 ± 0.16^{x}	20.7 ± 0.31^{xy}	19.7 ± 0.25^{y}	0.018
Final EBF (%)	35.91 ± 0.286^{xyz}	35.66 ± 0.098^{xz}	35.83 ± 0.195^{x}	35.17 ± 0.156^{z}	0.016
CT_EBF (%)	27.94 ± 0.611^{xy}	27.39 ± 0.210^{x}	26.28 ± 0.418^{xy}	26.26 ± 0.337^{y}	0.004
Carcase fat (%)	30.92 ± 0.661^{xy}	30.32 ± 0.227^{x}	29.13 ± 0.452^{xy}	29.10 ± 0.365^{y}	0.004

[A]Values are estimated marginal means, standard error of the mean (SEM); x, y, z means without a common superscript differ ($P < 0.05$).

Results from the present study suggest that CVDS could be able to predict animal performance, body composition and carcase traits among cattle breeds and therefore, confirming our hypothesis. However, future research should aim to improve the accuracy of predictions and further refinement of the model. A slaughter trial should use the most important Australian beef breeds with incremental days on feed, with full dissection and chemical analysis of body sections to understand it composition (e.g. proportion of meat, fat and bones) and associations with animal growth and body weight. The subsequent data would be beneficial to test the accuracy of current prediction models for feedlot use. Future studies to further refine this model for domestic use could prove to be potentially advantageous for the beef feedlot industry in optimising productivity and profitability.

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Dystocia in cattle: a systematic literature review

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A difficult or prolonged calving, known as dystocia, can impact on cow and calf survivability and postpartum health and performance (Barrier and Haskell, 2011; Barrier *et al.* 2012). Consequently, calving is often carefully monitored to ensure early intervention and assistance can be administered where required. Traditional monitoring techniques, which primarily involve experienced farm staff checking on animals, is time consuming, labour intensive, and often not feasible in extensive environments. Precision livestock technologies could instead be utilised to monitor calving and identify dystocia. This first requires an understanding of the behavioural and physiological differences between dystocia and eutocia. As such, the purpose of this study was to evaluate the available literature pertaining to dystocia and to determine what characteristics might differ between dystocia and eutocia (normal calving) that might be detected by on-animal sensor systems.

As part of a broader systematic literature review, scientific databases (BioOne, ProQuest, ScienceDirect, and Web of Science) were searched in March 2018 using the following terms: 'behaviour*', 'birth*', 'calf', 'calving*', 'cow*', and 'parturition*' (Chang *et al.* 2020). Articles were included in the analysis if they were (i) written in English, (ii) used cattle as the primary subjects, (iii) occurred within 1 month of parturition, and (iv) described dam behaviour and/or physiological changes in response to dystocia.

A total of 729 articles were identified, 11 of which compared cow behaviour during dystocia and eutocia. Twenty-four behavioural and physiological indicators were reported, the majority of which were only identified in one study each. Several indicators, including tail raising and feeding time, were reported in multiple studies, however, conflicting results were observed. The most common and consistently reported difference between dystocia and eutocia was length of parturition (n = 5), with dystocia being associated with extended periods between the stages of parturition (Fig. 1). Three indicators (lying bouts, standing, and walking) were not observed to differ between dystocia and eutocia.

Interestingly, 5 dystocia-based literature reviews were identified during the search process; however, these primarily reported on the causes or implications of dystocia on the cow and calf.

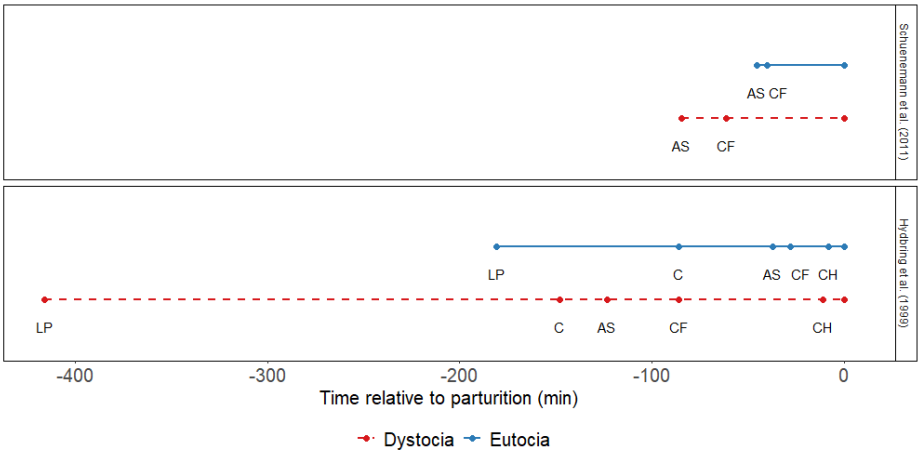

Fig. 1. Timeline of stages of parturition in dystocia and eutocia in minutes relative to parturition. Dystocia is depicted in red, while eutocia is depicted in blue. AS = amniotic sac, C = contractions, CF = calf feet, CH = calf head, LP = labour pains.

The results of this study indicates a lack of dystocia-based research, despite the availability of literature reviews on the topic. Furthermore, these findings suggest a lack of repeatable dystocia indicators, with the exception of parturition length. Consequently, additional research would be of value to further understand the differences between dystocia and eutocia in a wider range of environments and with varying parities and breeds.

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Effect of encapsulated fennel extract on motility and viability of frozen-thawed ram sperm

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The objective of current study was to investigate the effects of encapsulated fennel extract on motility and viability of frozen-thawed ram sperm. Success in artificial insemination and pregnancy in animal husbandry is directly affected by sperm quality. Induced damages during cryopreservation decrease sperm quality which is followed by the increasing of reactive oxygen species (ROS) and oxidation of polyunsaturated fatty acid (PUFA) in the membrane and consequently decreasing motility, viability and membrane integrity (Del Omlo *et al*. 2015).

A total of 6 mature Ghezel rams were housed and maintained under natural photoperiod using conventional feeding conditions. A total of 36 ejaculates were collected from the rams during the breeding season. After primary evaluation, ejaculates were pooled during every semen collection to eliminate individual effects and then were divided into equal aliquots for extending. The experimental groups were Con (Control group; extender without any fennel extract), FEN_{ext} (extender containing 10 mg/L fennel extract) and FEN_{cap} (extender containing 10 mg/L fennel extract loaded into nanophytosome). The concentration of fennel extract was used according to a previous study (Najafi *et al*. 2019). Encapsulation of fennel extract was carried out with cholesterol and phosphatidylcholine, using the thin-layer hydration method explained by Najafi *et al.* (2018).

Table 1. Effect of encapsulated fennel extract on motility and viability of frozen-thawed ram sperm

Traits	Experimental groups			SEM
	CON*	FEN_{ext}	FEN_{cap}	
TM (%)	50.25^{c}	56.91^{b}	62.76^{a}	1.04
PM (%)	25.23^{c}	27.66^{b}	31.08^{a}	0.81
VAP (µm/s)	64.35^{c}	69.2^{b}	72.10^{a}	0.84
VSL (µm/sec)	51.21^{c}	55.23^{b}	58.87^{a}	0.75
VCL (µm/sec)	112.93^{b}	115.22^{a}	116.69^{a}	0.75
ALH (µm)	5.53^{b}	5.93^{a}	6.02^{a}	0.13
BCF (Hz)	23.22^{b}	25.73^{a}	27.13^{a}	0.64
Membrane integrity (%)	50.05^{c}	53.63^{b}	58.29^{a}	0.698
Viability (%)	55.17^{c}	60.56^{b}	64.93^{a}	0.648

Note: Different superscripts within the same column indicate significant differences among groups (P<0.05); CON: Control, FEN_{ext}: fennel extract, and FEN_{cap}: fennel extract loaded into nanophytosome; TM: Total motility (%), PM: progressive motility (%), VAP: average path velocity (µm/s), VSL: straight linear velocity (µm/s), VCL: curvilinear velocity (µm/s), LIN: linearity (%), STR: straightness (%), ALH: amplitude of lateral head displacement (µm), STR: straightness (%) and BCF: beat cross frequency (Hz).

Table 1 shows the influence of the various forms of fennel extract (FEN_{ext}) and fennel extract-encapsulated (FEN_{cap}) on sperm motility and kinematic variables after cryopreservation. FEN_{cap} and FEN_{ext} resulted in a higher ($P < 0.05$) total and progressive motility after thawing compared with the control (CON) group. Also, other motility parameters were higher in the FEN_{cap} group than CON ($P < 0.05$). Although no significant differences were found between FEN_{ext} and FEN_{cap} groups in amplitude of lateral head displacement (ALH) and beat cross frequency (BCF) ($P > 0.05$) but curvilinear velocity (VCL), linearity (LIN) and straightness (STR) were significantly higher in FEN_{cap} than FEN_{ext} ($P < 0.05$). Also, FEN_{ext} had significant differences in all motility parameters versus control group ($P < 0.05$). Fennel extract and fennel extract-encapsulated significantly increased sperm viability and membrane integrity in comparison with control group ($P < 0.05$). Also, higher amounts of mentioned parameters were observed in the FEN_{cap} group compared with the FEN_{ext} group ($P < 0.05$). According to the results, it seems supplementation of semen extender with fennel extract-encapsulated increases the sperm viability and progressive motility during cryopreservation which can be beneficial in artificial insemination.

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Sensory evaluation of farmed goatmeat by Australian consumers

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The top three barriers to purchasing goatmeat for Australian consumers have been defined as familiarity, availability and not knowing how to cook it, followed by a dislike for taste and smell (MLA 2020). However, with record prices offered for slaughter and breeding goats, there is an opportunity to develop and market high quality goat meat to domestic consumers. To address the issue of familiarity and cooking style, this study presented goatmeat in a way that is familiar to an Australian consumer: grilling. It was hypothesised that grilled goatmeat would yield acceptable responses from Australian consumers.

The *m. longissimus lumborum* (loin), *m. longissimus thoracis* (rack), and *m. gluteus medius* and *m. biceps femoris* (rump) were collected from 12 milk tooth Boer goat wether carcasses and utilised for sensory testing using protocols described by Thompson *et al.* (2005). The quadriceps group (*m. rectus femoris*, *m. vastus lateralis* and *m. vastus intermedius*; knuckle) was used as a linkage sample. Sensory samples were scored for tenderness (T), juiciness (J), flavour (F) and overall liking (O) using a 100 mm visual analogue scale, providing a score out of 100 points. Sensory data were analysed using the linear mixed effects function (*lmer*) in the R environment (R Core Team 2021), with cut as a fixed effect and carcass as the random term. Estimated marginal means (EMM) were calculated using the *emmeans* package (Lenth 2021) and pairwise comparisons used to determine the eating quality differences between cuts.

Goat cuts scored (mean ± SD) 51.3 ± 12.1 points for T, 54.6 ± 8.5 points for J, 60.1 ± 7.5 points for F and 56.8 ± 9.7 points for O. There was a difference between cuts for T, J, F and O ($P < 0.05$, Fig. 1). Rump and rack were scored (difference ± SE) higher for T than loin by 16.19 ± 3.35 and 9.97 ± 3.35 points respectively ($P < 0.05$), while the knuckle was not different ($P > 0.05$). Juiciness scores were higher for rump and knuckle as compared to loin and rack ($P < 0.01$). Scores for F were lowest in the loin (55.6 ± 2.09), with rump (62.3 ± 2.09) and rack (61.6 ± 2.09) scoring higher ($P < 0.05$) and knuckle (60.9 ± 2.66) scoring similarly ($P = 0.207$). Overall liking of cuts was highest for rump, being 9.84 ± 2.86 points higher than loin ($P = 0.01$). However, rump was not different to rack and knuckle ($P > 0.05$).

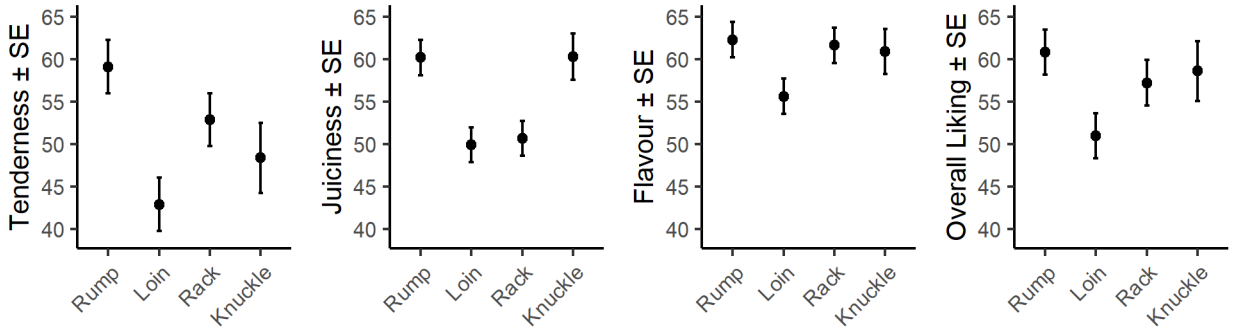

Fig. 1. Estimated marginal mean consumer sensory scores ± SE for grilled lamb rump, loin, rack and knuckle.

Lower consumer tenderness scores, of the loin particularly, may have been driven by cold shortening at slaughter. The carcasses did not receive electrical stimulation, which is known to improve tenderness in goats (Gadiyaram *et al*. 2008). Thompson *et al.* (2005) reported average consumer sensory scores for unstimulated lamb grills similar to results from the current study. The same authors reported consumer sensory scores from loins that were scored 14 to 36 points higher than loins from the current study for T, J, F and O; however, these results incorporated both stimulated and unstimulated lambs which may have had intrinsically higher eating quality. Regardless, it is clear that there is a need to control post slaughter factors that may impact on goatmeat eating quality and domestic consumer acceptance of goatmeat.

This study highlighted that goatmeat from high quality carcasses was acceptable to consumers. Goatmeat has the potential to offer a premium product, especially if processing factors impacting eating quality are managed; however, more cut x cook research is required to enable this.

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Detection of bovine respiratory disease associated agents from feedlot trough water at two time-points from three commercial NSW beef feedlots

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Bovine respiratory disease (BRD) is the most prevalent disease in feedlot cattle populations worldwide. It is a multifactorial disease complex with many bacterial and viral agents attributed to clinical disease. Shared water troughs between adjoining feedlot pens, has been shown to increase BRD risk (Barnes *et al.* 2015), however, the cause of this increased risk is not well understood. The objective of this study was to better understand the prevalence of BRD associated agents (Bovine herpesvirus 1 (BHV-1), *Histophilus somni, Mannheimia haemolytica, Mycoplasma bovis, Pasteurella multocida* and *Trueperella pyogenes*) in the Australian feedlot system, we compared the prevalence of these agents in water samples from induction pens, sampled over two time-points from three NSW feedlots, using quantitative PCR. We hypothesised that water troughs shared between adjoining pens would have a higher burden of BRD associated agents than troughs that only serviced individual pens.

Water samples (50 mL) were collected between January 2021 and July 2021, from home pen water troughs at three commercial feedlots (Feedlot 1–3) located in New South Wales over two time points; induction (day 0) and again after two weeks (day 14). A total of 20 water samples were collected from 10 water troughs day 0 and day 14 (Feedlot 1 $n = 2$, Feedlot 2 $n = 4$, Feedlot 3 $n = 4$; Charles Sturt University ACEC Protocol A21092). Feedlot 1 and 3 had shared water troughs between adjoining pens while Feedlot 2 had individual water troughs for each pen. All water samples were stored at –80˚C and were thawed slowly at 4˚C prior to DNA extraction. A portion of each water sample (10 mL) was centrifuged (2630 RPM) for 10 min and the supernatant was removed. Sterile phosphate-buffered saline (PBS, 100µL) was used to resuspend the pellet for direct heat extraction (boiling at 100 for 10 min). Multiplex PCR was performed on all samples using previously published primer sequences (Kishimoto *et al.* 2017), with minor modifications.

Generally, water trough samples from Feedlot 1, regardless of time-point, had more detectable agents than Feedlots 2 and 3 (Fig. 1). This may be attributed to the troughs being shared in Feedlot 1; however, this was not the case at Feedlot 3 which also had shared water troughs. *Mannheimia haemolytica* and *P. multocida* were only detectable from Feedlot 1 water troughs (Fig. 1). While *M. bovis* was only detectable from two samples, both collected at day 0 (Feedlot 1 and 2; Fig. 1). There appeared to be no notable relationship between sample collection time-point and the number of detectable BRD associated agents.

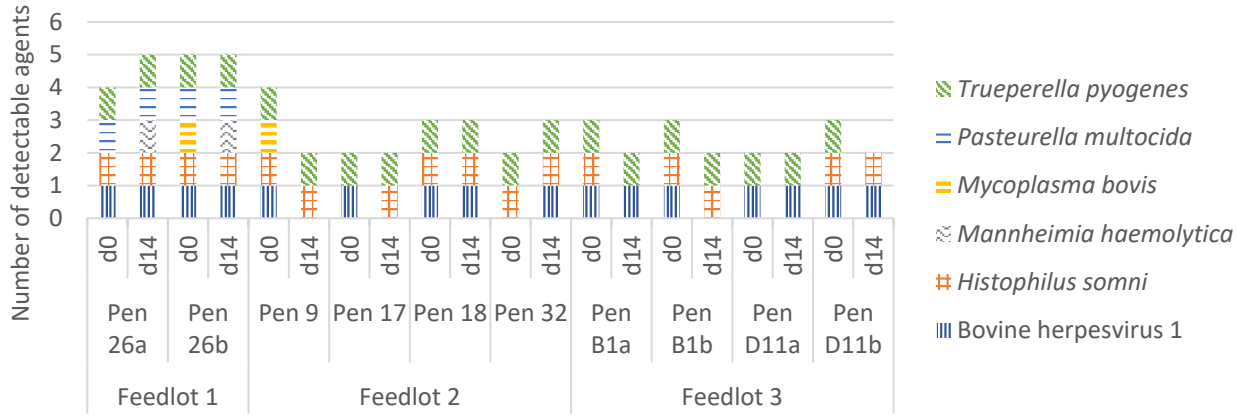

Fig. 1. Number of detectable bovine respiratory disease associated agents from home pen water troughs collected at two time-points (day 0 (d 0) and day 14 (d 14), $n = 10$) from three commercial feedlots located in New South Wales.

In conclusion, this study is the first to report on the detection of BRD associated agents from water trough samples collected from commercial Australian beef feedlots. This study has provided a promising foundation for further research into the relationship between shared water troughs in feedlots and increased BRD risk. With the addition of accurate quantification, the technique used in this study could be used as an environmental monitoring tool to determine BRD risk in beef feedlots.

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In vivo rumen microbial degradation of polyhydroxyalkanoate biopolymers

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Polyhydroxyalkanoates (PHAs) are biopolyesters which are synthesised and stored in the cell cytoplasm as water-insoluble inclusions by various microorganisms (Anderson *et al.* 1990). PHA biopolymers, are water insoluble, stable at a variety of pH and have been shown to be degraded and used as nutrients by soil bacteria and fungi (Megaert *et al.* 1993), making them ideal candidates as novel delivery systems to provide controlled slow release of included compounds into the rumen of cattle. To understand the biodegradation characteristics of PHA within the rumen environment, a 122-day animal trial was undertaken in a repeated-measures, randomised-block design with three fistulated animals used to determine between animal variations. Two replicate sets of PHA biopolymer samples were placed in the rumen of each animal allowing measurement of within animal variation (Animal Ethics Committee approval SA 2020/03/737).

Extruded 'solid' cylinders or 3D printed 'porous' cylinders were prepared from PHA biopolymer using a two-step process; dry mixing followed by melt compounding and extrusion using a co-rotating twin screw extruder with a diameter of 16 mm for the solid cylinder. To enable 3D printing, the PHA, it was first extruded as a 1.6 mm filament which was used in a 3D printer. The biopolymer pieces were dried, weighed and placed into numbered nylon bags secured with nylon fishing line. These bags, containing the allocated sets of biopolymer pieces, were placed into two nylon mesh bags per animal, inserted into the rumen of each animal via the rumen cannula and secured with a nylon rope. The nylon mesh bags were withdrawn via the cannula on days 30, 62, 92 and 122, and the specific numbered bags of biopolymer pieces assigned for removal at each timepoint removed. The biopolymer pieces were recovered, rinsed with reverse osmosis water and dried. Percentage weight loss, and analysis by scanning electron microscope (SEM), differential scanning calorimetry (DSC) and gel permeation chromatography (GPC) was undertaken for each biopolymer piece.

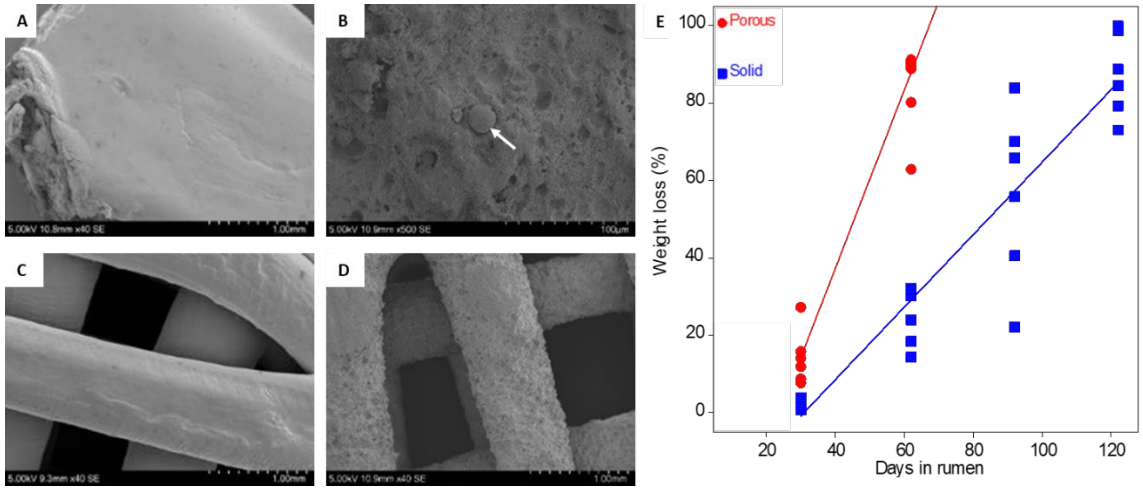

Fig. 1. SEM images of pieces of (A) solid PHA prior; (B) solid PHA after 30 days in the rumen (with a bacterial cell indicated with an arrow); (C) porous PHA prior; (D) porous PHA after 30 days in the rumen; and (E) linear regression analysis of degradation rate of solid (blue square) and porous (red circle) biopolymer pieces in the rumen over time.

The surfaces of representative solid and porous samples were analysed using SEM which showed that surface erosion was the dominant pattern of biodegradation. Prior to placement in the rumen, all the samples presented a smooth surface (Fig. 1A, C) whereas after 30 days in the rumen, both the solid and porous PHA samples had a large number of holes and hemispherical divots on the surface, indicative of bacterial enzymatic degradation (Fig. 1B, D). Linear regression analysis showed that the solid and porous PHA biopolymers degraded at significantly different rates ($P < 0.001$) with the porous samples degrading 2.46 times more rapidly than the solid biopolymer (Fig. 1E). DSC analysis revealed consistency in the melting behaviour of PHA and the GPC showed molecular weight consistency in the highly degraded samples, both confirming that in the rumen environment surface erosion is the dominant degradation pattern. The surface erosion biodegradation of the PHA biopolymer pieces *in vivo* in the rumen over the 122 days is a very promising first step for the use of biopolymers as novel delivery platforms for the controlled slow release of compounds into the rumen of cattle.

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Factors affecting lamb birth weight, gestation length, survival and litter size in Poll Dorset sheep

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In NSW, lamb mortality ranges between 10–35% (Hinch and Brien 2014), but this figure varies according to season, location, litter size and breed. Improving the survival of lambs is essential for industry social license and on-farm productivity. Refshauge *et al*. (2016) highlight the litter size effects on causes of death, with twin and triplet lambs having higher mortality rates than singles. The objective of the present research was to assess the effect of birth weight, litter size, wool length (shorn or not shorn during pregnancy), gender, conception type (artificial insemination or natural joining), on the dependent variables of birth weight, gestation length, survival, and litter size. Survival was analysed using a logistic regression model and the other variables using a linear regression model in R Studio (v 4.1.0; R Core Team 2021).

All experimental procedures were approved by the institutional Animal Ethics Committee from The University of Sydney (Approval 2020/1730 and 2016/983). The present study used 445 mixed age Poll Dorset ewes with a pregnancy scanning rate of 151% and 126%. The trial was conducted in Bowan Park near Cudal, New South Wales, Australia using 11 paddocks (178 ha) with oats crops, native pasture and lucerne. All ewes and lambs had access to a loose waterproof molasses granular lick feed (NUTRI-mins Ewe and Lamb).

Table 1. Factors affecting lamb birth weight, gestation length, lamb survival and litter size

	Wool length	Gender	Litter size	Conception type	Birth weight	Birth weight[2*]
Birth weight, kg	<0.001	<0.001	< 0.001	0.002	-	-
Gestation length, d	0.084	0.023	<0.001	-	-	-
Survival, %	0.210	0.250	<0.001	0.092	-	-
Survival, % (with birth weight)	0.610	0.063	0.810	0.640	<0.001	<0.001
Litter size, #/ewe	<0.001	0.460	-	<0.001	-	-

*Quadratic effect of birth weight.

None of the two- or three-way interactions affected any of the variables except for wool length × little size on survival ($P < 0.05$) with quadruplets being more likely to survive in shorn compared to unshorn ewes. Lambs born to shorn ewes were heavier at birth and had larger litters compared to those born from unshorn ewes ($P < 0.001$; Table 1). Lambs born from a natural joining were heavier and had smaller litter sizes compared to those born from artificial insemination ($P < 0.05$) but this did not affect lamb survival ($P > 0.05$). Birth weight was affected by litter size which affected survival ($P < 0.001$). A logistic scale formula was created to predict survival according to the birthweight of the lamb. This curvilinear relationship provided a clear association of body weight and survivability. Poll Dorset lambs whose body weights were ranging between 4-7kgs when born had the highest chance of survivability >80% (data not shown).

The results of the present study have practical implications provide a greater understanding for the health and welfare of Poll Dorset lambs. Single factors that influence the variation in the lamb birth weight, gestation length, survival and litter size of lambs is important for sheep producers to understand within their farming environment. Researchers acknowledge that the continued increase of data collection and analysis of these factors across a variety of environments will not reduce mortality. But only if action is taken to control them will greater animal welfare outcomes be achieved. Further and continued research in this field of lamb survival within a changing environment is encouraged.

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An investigation into determining if chiller location can account for the variability of electrical stimulation in automatic lamb chillers

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The current Australian lamb industry pH and temperature compliance guidelines have been generated based on conventional chilling systems. There is limited literature available on pH and temperature declines on lambs processed using automatic chillers, and it is unknown if chiller hook location in automatic chillers impacts lamb carcase pH and temperature compliance. The objective of this study was to determine the impact of chiller hook location on stimulated (low voltage electrical stimulation LVES, <110V) and non-stimulated lamb carcases being chilled in automatic chillers. It was hypothesised that automated lamb chiller hook positions will influence the lamb carcase pH and temperature declines.

A total of 480 lamb carcasses were commercially processed at an export accredited sheep processing facility in New South Wales. All carcasses were allocated to either non-electrically stimulated (n = 240) or LVES stimulated (n = 240) treatment groups, prior to entering the automated chillers onto chiller rail hook locations, listed 1–14, from left to right. The hook location was recorded upon entry into the chiller and remained the same for each carcase as it moved throughout the length of the chiller. Individual carcase pH and temperature measurements were recorded on for individual carcasses at the caudal section of the loin (*m. longissimus thoracis et lumborum*) over four time points during carcase chilling. The initial reading 1 was measured when carcasses entered chiller 1, reading 2 and 3 were measured with ~1.5 h between each reading and a fourth reading was recorded ~24 h after reading 1. All data was statistically analysed using the R environment within RStudio using the linear mixed models' package *lme4* (RStudio Team 2018) and mean temperatures at the 14 automatic chiller hook positions for reading 1, 2, 3 and 24 h was generated in Microsoft excel using full dataset. There was a significant effect between chiller hook position on temperature ($P < 0.0001$) and reading ($P < 0.0001$) where chiller hook position had an impact on temperature as well as reading. LVES had a significant impact on pH decline, resulting in all lamb carcases achieving the industry pH decline acceptability window (pH 6.0 between 18–25˚C). Carcase hook location in the chillers were significantly impacted, where the middle carcase temperature decreased slower compared to the outside chiller locations (Fig. 1).

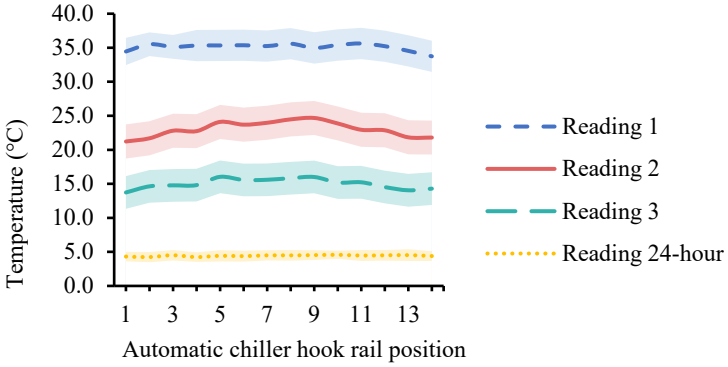

Fig. 1. Mean temperature (°C) at automatic chiller hook rail position for reading 1, 2, 3 and 24 h. Readings are differentiated by their different colour. The 95% confidence interval have been plotted as shaded lines to the primary curves. There were 14 rails in the chillers and were listed as 1–14 from left to right (left being the side where the carcasses entered the automatic chiller).

This study demonstrated that there was a significant relationship between LVES pH and temperature decline and chiller hook position in an automated chiller. In comparison to conventional chillers, where carcases are suspended in one location on a rail during the chilling period, automated systems require further understanding on factors influencing the chilling process such as position on the rail and air movements directly impacting carcase chilling. This study concluded that LVES was effective in reaching optimal pH and temperature decline and aligning with the current industry compliance guidelines. The conclusions from this study should be considered when lamb processing plants are implementing automated chilling technology.

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Using historic data to understand the cost of an extra condition score in sheep

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Below optimum body condition in sheep is associated in its extreme with death due to malnutrition and at lesser levels with reduced reproduction and productivity. Producers who need to increase ewe body condition are forced to change their management practices to increase feed available, which comes at a cost. A long-term solution is to breed for a ewe that is better able to meet the body condition targets of the production system. An industry led desire within maternal and Merino based sheep operations is to increase genetic condition within the breeding objective and this requires an understanding of the bio-economic value of body condition in adult ewes specific to each production system.

The following study compiled body condition score (BCS) and liveweight data from the MERINOSELECT (Brown *et al.* 2007) database, which incorporated data from both industry and research flocks. In sheep, BCS is a subjective measure of fat and muscle coverage over the anterior lumbar vertebrae and scored on a 1 to 5 scale. BCS records with a corresponding weight record from across the production cycle were available for 489 723 Merino and Maternal Merino cross animals. From the phenotypic relationship between the traits the potential to use the metabolisable energy (ME) requirements for weight gain in Freer *et al.* (2007) to infer the ME requirements to gain a BCS was explored. The dataset was further reduced to 243 432 records considering only adult ewes, filtering to remove extreme records (BCS or weight 2 standard deviations (sd) greater than cohort means), low variation cohorts (sd less than 0.25 BCS) and cohorts with less than 30 records. The final dataset had a mean weight of 57.7 kg (sd = 11.4 kg) and mean BCS of 3.0 (sd = 0.6). Regressions of BCS on weight with and without the cohort interaction were estimated using the linear models (lm) function in R (R Core Team 2013) using liveweights and BCS standardised to the cohort mean for that trait to account for mean differences. Cohorts (n = 1758) were defined based on the individual dataset standards, which grouped ewes who are managed together and measured on the same day. The ME requirements to gain a single condition score were then extrapolated based on the ME requirements for weight gain for Merino sheep in Freer *et al.* (2007).

Across all data a BCS change was found to be associated with a 5.31 ± 0.03 kg (R^2 = 0.13) response in liveweight. Based on the equations from Freer *et al.* (2007) to achieve an extra BCS would require approximately 307 MJ of ME. Which means to gain the extra BCS the 57.7 kg ewe will need to consume approximately 1.4 times the maintenance ME after weaning a lamb (~4-month dry period) compared to a ewe of equal weight that meets BCS targets at joining.

In a study of Irish terminal breeds an extra BCS was associated with a 4.8 kg change in liveweight (McHugh *et al*. 2019). However, in both this study and that of McHugh *et al.* (2019) the relationship varied across groups of animals. Fitting regressions within cohort produced a weighted mean regression coefficient of 6.2 kg/BCS, and weighted sd of 4.5 kg/BCS across cohorts. This equates to a mean ME requirement across cohorts of 325 MJ (sd = 237 MJ) for an increase of 1 BCS. As reported in McHugh *et al.* (2019) the relationship varied across breed type and it is hypothesised that this is due to differences in body type or frame score. Unfortunately, frame or height measures are not routinely recorded in industry or research flocks. The mean liveweight of the cohort can provide the potential impact of sheep type on the relationship in question. A 1 kg increase in the mean liveweight of the cohort is associated with an extra 0.14 ± 0.02 kg per BCS change (R^2 = 0.07). This suggests a 55 kg ewe would be required to gain 6.3 kg/BCS compared to 5.1 kg/BCS for a 45 kg ewe, at a cost of 70 MJ of ME above that required by the smaller ewe to gain a BCS.

Ultimately, a study across Merino types that can quantify ME requirements associated with change in BCS and the underpinning energy reserves in fat and muscle tissue is still desired. Morel *et al.* (2016), provides an indication of the expected ME requirements for a BCS change, estimating that moving from BCS 2.5 to 3.5 in a 54kg Romney cross ewe requires 391 MJ of ME above maintenance (equated to 5–10 kg). This is similar to the estimate achieved based on the linear equations estimated from this study of 325 MJ for a 54 kg Merino ewe. However, the Morel *et al.* (2016) study has highlighted that the ME required to move between BCS is not linear, something that could not be investigated here.

The results from this study can provide the initial start to modelling the importance of body condition at joining within a breeding objective. The ME cost associated with changing condition score on ewes at joining can provide an indication of the extra feed required in the recovery period after weaning to achieve joining condition targets. Based on the hypothesis by Walkom *et al.* (2016), that genetically fatter animals are genetically fatter at all ages and across the production cycle, selection for fat and muscle is likely to lead to ewes in better condition at joining either through improved maintenance efficiency, appetite or changes to body composition. The results within this study go some way into describing the likely value, via reduced feed requirements, of selecting for more genetic condition in breeding ewes.

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The origin of rare reducing sugar, trehalulose, in Australian stingless bee honey

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Trehalulose, an atypical glucose-fructose disaccharide with α-(1→1) glycosidic bond, has known low glycemic index, and acariogenic properties (Tian *et al*. 2019), as well as antioxidant activity (Kowalczyk *et al*. 2015). It has been discovered as the dominant sugar (13%-44%) in Australian, Malaysian and Brazilian stingless bee honey samples (Fletcher *et al.* 2020). Floral nectar is an aqueous mixture of glucose, fructose and sucrose, and the natural presence of trehalulose in stingless bee honey is highly curious. This study aimed to investigate the effect of feeding sugars to stingless bees on the sugar composition of their honey. By feeding sucrose and glucose/fructose solutions to confined stingless bees, this study established the origin of trehalulose and gained insight into optimization of its level in stingless bee honey.

Microcolonies of the Australian stingless bee species *Tetragonula carbonaria* were created by transferring brood, adult bees and cerumen from established colonies into specially designed boxes with large viewing windows, which allowed detailed observation of all parts of the nest throughout the feeding experiments. Transferred stingless bees were permitted free forage for 3 days with small amount of supplementary food. During the feeding experiment, the microcolonies were confined to the box, and external liquid feeders were attached to the entrance. Sucrose solution (50:50 sucrose/water) or 1:1 glucose/fructose solution (25:25:50 glucose/fructose/water) were placed into the external feeder. During each period of confinement, bees were observed concentrating the sugar solutions into honey and filling honey pots. Honey samples were transferred by pipette from the honey pots, which were filled and capped during the confinement. The sugar composition of these honey samples was analysed through liquid chromatography-mass spectrometry (LC-MS/MS) and ion chromatography (IC-PAD).

Table 1. Sugar composition (% of total sugar) of honey from confined stingless bee sugar feeding experiments

Sugar fed	Sample code	Glucose (%)	Sucrose (%)	Fructose (%)	Trehalulose (%)	Erlose (%)
Sucrose	S1	0.4	ND	10.3	71.6	17.8
Sucrose	S2	ND	ND	8.8	68.7	22.5
Sucrose	S3	1.0	ND	10.3	67.7	21.0
1:1 glucose/fructose	GF1	45.0	ND	55.0	ND*	ND*
1:1 glucose/fructose	GF2	47.6	ND	52.4	ND*	ND*
1:1 glucose/fructose	GF3	48.6	ND	51.4	ND*	ND*

ND, not detected.

Trehalulose was the most abundant sugar (67.7–71.6%) formed in the sucrose feeding experiments S1, S2 and S3 (Table 1). A novel trisaccharide erlose was detected for the first time, at 17.8–21.0%. Monosaccharides, glucose and fructose, were detected in low amounts. In the 1:1 glucose/fructose feeding experiments GF1-GF3 (Table 1), trehalulose, sucrose and erlose were not detected. The resultant 'honey' contained glucose and fructose in the same 1:1 ratio as per the feeding solution.

From these feeding experiments, it was demonstrated that sucrose can be directly converted into trehalulose by live stingless bees. Feeding sucrose solutions resulted in honey that contained mostly trehalulose, erlose and fructose. In contrast, feeding 1:1 glucose/fructose solutions to stingless bees resulted in no conversion to trehalulose. In conclusion, stingless bees are able to produce trehalulose from the isomeric disaccharide sucrose, not directly from the monosaccharide components, glucose and fructose. Improving the trehalulose levels in stingless bee honey would involve locating nectar high in sucrose and optimizing bee access to that nectar. Further work using isotopically labelled sugars is required to elucidate whether the conversion of sucrose to trehalulose is an intermolecular or intramolecular process.

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The Bloat Alert app: an early warning app for bloat in cattle

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Frothy bloat in cattle is a major cost to producers in southern Australia (Lane *et al*. 2015). Its sudden and often unpredictable nature, and the inability of current preventive measures to be fully effective, results in unexpected losses of cattle. Bloat typically occurs on highly digestible high-protein forages (Wang *et al*. 2012) such as legume dominant pastures (e.g. lucerne, subclover), and due to seasonal conditions determining the lushness and dominance within a pasture, bloat typically occurs on many properties at the same time of year within a region. The aim of the initiative reported was to provide producers with a warning system to know that bloat was occurring within their district, so that producers were better placed to implement appropriate preventive measures and thereby reduce stock losses.

The Bloat Alert app is a mobile app that was developed using the web application platform Firebase (Google 2011), and initially was only available for iPhone users. The app was available free via the Apple AppStore. In developing the app, the primary motivation was to produce an app that would encourage producer reporting of bloat, and thereby, through immediate notification, alert other producers within the region that bloat was occurring in that region. It was decided to identify producers via postcode rather than their specific property, thereby maintaining producer confidentiality but still informing producers that bloat was occurring in their area. The data required to submit a report was set to the minimum considered necessary, but additional information was able to be submitted. The app was developed with five main sections - an interactive map showing reported cases by postcode, a reporting section to allow submission of bloat cases, an alert section to list all reported cases, an information section with basic information on bloat and links to additional information, and a settings section to allow users to modify or set their details and notification settings.

On detection of a suspected case of bloat, producers with the app could submit a report. The report was set out to allow most options to be selected from either a button or drop-down list, to minimise needing to type in information. Required information to submit a report included: fatality (Yes/No), Date, Postcode, Pasture type, Age (select range – <1 year, 1–2 years, >2 years, Mixed) and confidence in diagnosis (slider from 0–100%, 10% increments). Additional information which could optionally be included in a report included: Time in Paddock (0–2 days, 2–7 days, 1–2 weeks, >2 weeks), Animals in mob (number), Animal Breed(s), Prevention methods used (Yes/No, if Yes selected, additional option to specify prevention methods) and Additional Comments (allowed any additional information to be provided).

On submission of a report, if the postcode listed for the cases was within the area of interest set by the producer using the app, that producer would immediately receive a notification that a bloat case had occurred. Bloat reports are visible on both the Alerts page and the interactive map for all users.

The app was launched in early July 2021, just prior to the expected highest risk period in southern Australia. Anecdotally bloat was less common in 2021 in southern Australia compared with 2019 and 2020, both the latter being considered severe risk years. By 30 September 2021 there were 230 registered users, and 28 bloat reports (from 22 July to 30 September). Of these 28 reports, 22 reports were for fatalities, with 27 reports in NSW and 1 report in South Australia. All 28 reports included details for Additional Information, suggesting producers found it easy to submit reports. For these 28 reports, Diagnosis Confidence ranged from 60% to 100%, with 20/ 28 reports being 90% (5) or 100% (15). The default starting point for the slider was 80%, so any figure other than 80% indicated the producer actively changed the slider. This occurred in 25/28 reports, showing Diagnosis Confidence was actively reported by producers. Some form of bloat preventive measures were reported for 16/28 cases, suggesting that existing preventive measures do not adequately prevent bloat. Reporting diagnosis confidence, having an easily submittable form and identifying bloat occurrences by postcode and not by actual farm were all considered essential to producing a useful and usable app, and all three appear to have been achieved, based on the responses from the early reports submitted.

The uptake and use of the Bloat Alert app strongly suggest that simple to use apps that facilitate producers assisting other producers preventing disease will be utilised. An Android version of Bloat Alert to allow even wider producer coverage is currently being developed for the 2022 season and it is expected that the use of the app will increase over time, at least initially. The app also provides opportunities for researchers to better understand the incidence of bloat and risk factors associated with outbreaks of bloat within a district, and to provide warnings of bloat occurrence by district. This app could be broadened to allow for the reporting of other diseases and used across other species in the future.

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Predicting biomass of heterogeneous pastures using a handheld NDVI sensor

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Estimating pasture biomass is critical for graziers to match stocking rate with pasture available. Many non-destructive methods including indirect, two-stage methods that involve calibration have been developed to alleviate time and costs when estimating pasture biomass (Trotter *et al*. 2010). Most current handheld technologies available for real-time pasture biomass have been targeted at the dairy industry because of the relatively homogeneous pastures. Active Optical Sensors (AOS) that use near-infrared and red light reflected from the plant can provide the normalised difference vegetation index (NDVI) which correlates with photosynthetically active plant biomass of the canopy. Previous studies with AOS have demonstrated the potential for application to estimate the green proportion of pastures (Trotter *et al*. 2010). The potential of the relatively low-cost AOS (Timble® GreenSeeker® Handheld, approximately A$700) to estimate green dry biomass (GDM) was assessed by Andersson *et al.* (2017) in grass-based homogeneous and mixed swards in Northern NSW, Victoria and Tasmania. The aim of our study is to report on the use of the GreenSeeker® to predict GDM in mixed-grass swards grazed by cattle on the Northern Tablelands of NSW. The current study was conducted between 25 May and 20 July 2021, inclusive. The study site and paddock layout are described by Dobos *et al.* (2021). Thirty-two pregnant Angus heifers varying in feedlot efficiency grazed within two groups of 16 (8 low and 8 high feedlot efficiency) heifers. Each group grazed one of 16, 0.61 ha paddocks of mixed perennial temperate grasses at 7-day intervals. Pasture measurements were recorded for 290 quadrats over the study period taken pre- and post-grazing and included a visual estimate of green biomass, rising plate meter height and NDVI (GreenSeeker®). Quadrats were cut to ground level and dried to calculate dry matter. High leverage data points were removed using Cook's distance metric to improve accuracy of regression. Data were randomly split 50:50 to create a model development set and a model testing set. NDVI from pre- and post-grazing data were subjected to regression analysis against GDM. Transformation of NDVI using log, square root, and quadratic against GDM was also conducted. Each model was assessed based on mean absolute error (MAE; to assess % error) and root mean square error (RMSE; to quantify the error of prediction). All analyses and calculations were achieved using the R statistical software (R Core Team 2021).

The pre-grazing mean (±SD) GDM was 4018 (1938.2) with a range of 571 to 12434 and NDVI was 0.39 (0.08) with a range of 0.17 to 0.66. The post-grazing mean (±SD) GDM was 2187 (1153.9) with a range of 277 to 5274 and NDVI was 0.28 (0.04) with a range of 0.18 to 0.47. Table 1 shows the performance of the prediction equations based on MAE and RMSE values from untransformed and transformed NDVI against GDM for pre- and post-grazing quadrat data.

Table 1. Performance of models for predicting green dry matter (GDM) from normalised difference vegetation index (NDVI) using a handheld sensor (GreenSeeker®) pre- and post-grazing from the test data set

	Pre-grazing (n = 77)*		Post-grazing (n = 62)*	
Equation	MAE	RMSE	MAE	RMSE
a+b NDVI	1626	2200	936	1200
a+b log (NDVI)	1624	2202	936	1198
a+b √NDVI	1625	2201	936	1199
a+b NDVI+c $NDVI^2$	1589	2159	935	1208

*Number of quadrats for the test data set after removal of influential data points. MAE, mean absolute error; RMSE, root mean square error.

This study demonstrated that there was a large prediction error for the GreenSeeker®, especially for pre-grazing models. Further investigations at different times of the year are required to assess this sensor for predicting GDM in mixed swards grazed by cattle. Also, combining with height may improve accuracy of predictions (Andersson *et al*. 2017).

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This work was funded by NSW DPI, CSIRO, University of New England (UNE) and the Meat & Livestock Australia (MLA) Donor Co. as part of Project P.PSH.1000 Increasing Profit from Pasture through Increased Feed Efficiency within the Livestock Productivity Partnership.

Can a robust prediction model be developed to predict the protein content of sheep meat using both lamb and mutton samples?

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Sheep meat is a valuable source of protein and is recognised by many as an essential component of a healthy diet (Arnason 2019), with the protein content being influenced by factors such as breed, diet, cut, and age of the animal (Chail *et al.* 2016; Hoffman *et al.* 2003). With the development of near-infrared spectroscopy (NIRS), quick and easy prediction of the protein content of a range of feeds and food products is increasing. However, studies on the prediction of the sheep meat protein content have been limited, particularly the impact of animal age on calibration models. Hence, this study was developed to see if a robust calibration could be developed to predict the protein content of sheep meat using a mixture of both lamb and mutton samples.

Samples for our study were sourced from various experiments conducted by the New South Wales Department of Primary Industries (NSW DPI) over the period of 2017–2020. Sheep slaughtered at commercial abattoirs, were subsampled, and sampled and further transported to the DPI Cowra, NSW, Australia, for further processing. Approximately 25 g of chopped lean meat was freeze-dried and ground to generate a homogenous sample and stored at -18°C until analysis. A total of 293 *M. longissimus* samples (195 lambs and 98 mutton) were used in this study. Protein content was determined by Dumas combustion based on AOAC method 992.15 (2012), where 0.5 g of freeze-dried meat was weighed into a porcelain sample holder (boat) for introduction into the combustion chamber (1300°C) of a Leco CNS 2000 analyser (Leco, St Joseph, MI, USA). Crude protein was calculated nitrogen (%) × 6.25 (AOAC 992.15:1992).

Glass NIR Vials measuring 2 cm x 4 cm were 3/4 filled with freeze-dried ground sample, tamped down to ensure even compaction, and allowed to equilibrate at room temperature for approximately 2 h. Samples were scanned on a BRUKER™ Multi-Purpose NIR Analyser, each of a total of 32 times with spectral data pre-treatment using mean centring and a 17-point smoothing function and frequency region of 3700 to 8500 nm. Individual sample scans were averaged to provide a single spectrum per sample.

Spectral data for all samples were imported into the OPUS software package (Bruker Optik™, version 7.5, 2014), where the distribution of the spectral population was checked by principal component analysis (PCA). The OPUS software randomly allocated sample scans into two subsets; a smaller independent validation set used to assess the model software, and a larger calibration set. A calibration was developed by analysing scan data from the calibration set using partial least squares (PLS) regressions within the OPUS software package. Once complete, the performance of the calibration model was validated using an independent dataset and evaluated using a root mean squared errors of prediction (RMSEP) were calculated.

Results for the calibration dataset containing 234 samples sourced from both lamb and mutton produced a calibration with an R^2 = 95.8 and SMECV = 0.79. Analysing lamb samples independently marginally improved the calibration (R^2 = 97.6 and SMECV = 0.56), while the regression for the mutton samples was slightly poorer than the combined equation (R^2 = 92.8 and SMECV = 1.14) and is likely due to the increased spectral scattering and variability within this sample set (Fig. 1). However, the diversity of samples is key to developing a robust calibration model, and the R^2 = 95.8 for our model shows that lamb and mutton samples can be successfully combined to produce a robust calibration model for predicting the protein content of sheep meat.

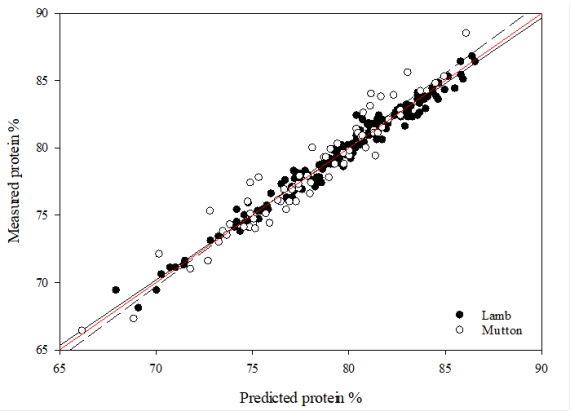

Fig. 1. Relationship between protein (%) determined using the Dumas method and predicted by near-infrared spectroscopy on freeze dried ground lamb and mutton.

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Impact of freeze drying and grinding method on spectral characteristics of lamb meat when analysed by near-infrared spectroscopy

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Laboratories use a variety of drying and grinding methods to prepare samples for near infra-red spectroscopy (NIRS) analysis, however the type of sample preparation used can have a significant impact on predicted results (Meyer *et al*. 2020; Osborne *et al*. 1983). This study examined the impact of two different freeze-drying and grinding methods on the spectral characteristics of lamb meat and resulting regressions for predicting intramuscular fat (IMF) when read on a BRUKER™ Multi-Purpose NIR Analyser, and whether inclusion of both types of preparation methods in prediction models would increase prediction accuracy.

Meat samples used in this study were sourced from commercial abattoirs for a variety of experiments conducted by the New South Wales Department of Primary Industries (DPI) over the period 2017–2021. Sample processing method varied according to source, with one set of samples freeze-dried at –50°C in a LaboGene, ScanVac CoolSafe™ freeze-drier and ground through a model 1095, FOSS Knifetech™ (FDK) laboratory mill, while a second set of samples had been freeze-dried at a commercial freeze-drying facility, before being ground to a fine powder in a NutriBullet™ blender (FDNB). Both groups of samples were then stored at –18°C until scanning.

Glass NIR Vials measuring 2 cm × 4 cm were 3/4 filled with ground sample, with frozen samples removed from the freezer and allowed to equilibrate at room temperature for approximately 2 h before scanning. Samples were scanned a total of 32 times with spectral data pre-treatment using mean centring and a 17-point smoothing function and frequency region of 3700 to 8500 nm. Individual sample scans were averaged to provide a single spectra per sample.

Spectral data for 307 FDK and 140 FDNB samples was imported into OPUS software package (Bruker Optik™, version 7.5, 2014), where the distribution of the spectral population was checked by principal component analysis (PCA). The plot of the PCA analysis (Fig. 1), where a clear difference between the spectral characteristics of two data sets can be seen; these differences often an indicator of an underlying treatment impact on spectral features (Alomar *et al.* 1999).

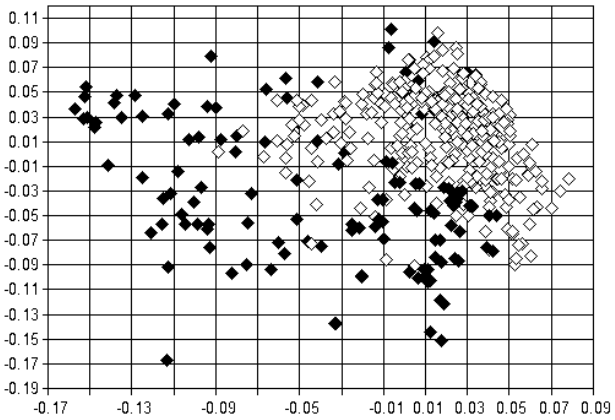

Fig. 1. Principal Component Analysis of the relationship between spectra processed by two different freeze-drying and grinding methods; white samples processed by a Knifetech™ mill and black samples by the NutriBullet™.

To determine the magnitude of these spectral differences, another 50 samples, which had been processed through a NutriBullet™ were selected at random and re-scanned on a Bruker Multi-Purpose NIR Analyser using 2 different IMF calibrations; one which had been developed using FDK samples and a second which had been developed using FDNB samples and a comparison was then made between the predicted IMF values from both calibration models. The correlation between predicted IMF values using both calibrations was high with an $R^2 = 0.94$ and SE = 0.11. As would be expected, there was a slight bias in favour of results predicted using the FDNB calibration, particularly in samples with IMF contents greater than 12%. While a slight bias adjustment could be made to account for this, a preliminary investigation into the impact of including of both higher fat content and FDNB ground samples into the FDK calibration model indicated that this would greatly reduce between model variations.

This study highlights the differences that can exist between different methods of freeze drying and grinding and in particular, shows the importance of selecting a robust sample set when developing calibration equations for predicting the IMF% of lamb. This is particularly important for commercial laboratories using NIRS to predict IMF%, where sample submissions can come from a variety of sources and have been processed using a variety of techniques.

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Effect of compaction on prediction of dried lamb lean tissue intramuscular fat and feed digestibility values predicted by near-infrared spectroscopy

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Near-infrared spectroscopy (NIR) enables rapid, accurate and inexpensive measurement of dried ground forage and meat samples; however, concerns exist that inadequate compaction of scanned ground samples can result in less accurate predictions. Therefore, this study was developed to see if the compaction of dried lamb and feed samples before scanning improved accuracy the accuracy of NIR predictions.

Samples of lamb lean tissue (meat: n = 31) and feed (n = 30) that had previously been prepared and analysed for intramuscular fat (IMF) content and dry matter digestibility (DMD) respectively (AOAC method 991.36 and AFIA method 1.7R) were scanned on a BRUKER™ Multi-Purpose NIR Analyser. Lamb loin samples were sourced from a commercial abattoir in Gundagai, NSW, while feeds (forages, total mixed rations, concentrates) were selected at random from commercial samples sent to the NSW DPI Feed Quality Service in Wagga Wagga, NSW.

Briefly, approximately 25.0 g of chopped lean meat was freeze-dried, ground to generate a homogenous sample and were stored at –18°C, while approximately 100 g of fresh feed was dried at 80°C in a forced draught oven, ground through a Perten™ laboratory mill (1mm screen) and stored at room temperature. Meat samples were removed from the freezer and allowed to equilibrate at room temperature for approximately 2 h before scanning. Glass NIR Vials (2 × 4 cm) were 3/4 filled with sample, tapped on a bench to pack and scanned. All vials were then compacted using a small plunger and rescanned. Each sample was scanned 32 times across a frequency range of 3700 to 8500 nm and averaged to provide a single prediction per sample, with spectral data pre-treatment using mean centring and a 17-point smoothing function. Spectral data for all samples was imported into the OPUS software package (Bruker Optik™, version 7.5, 2014), where the distribution of the spectral population was checked by principal component analysis.

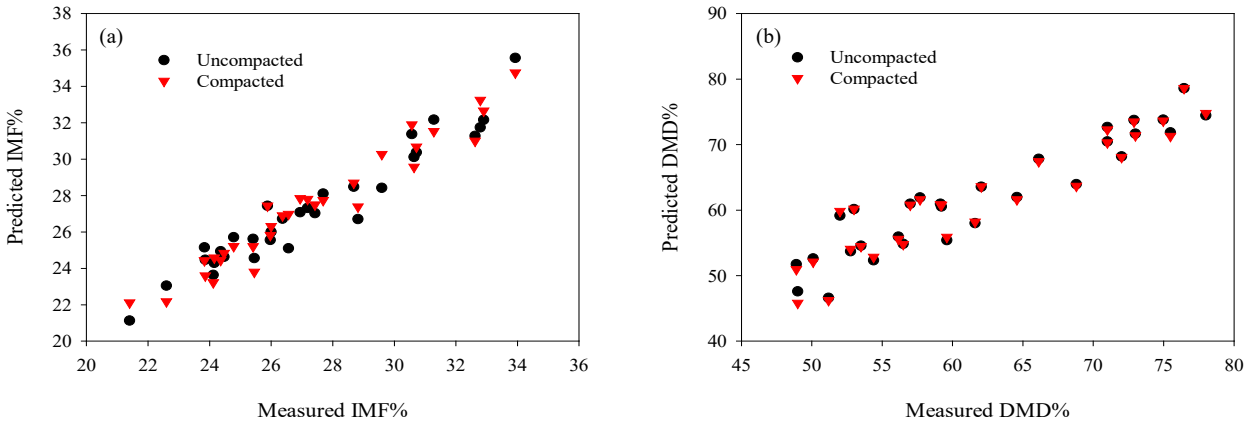

Fig. 1. Relationship between (a) measured and predicted intramuscular fat (IMF %) of freeze dried, ground lamb meat and (b) measured and predicted dry matter digestibility (DMD %) of dried, ground feeds.

The relationship between measured and predicted values can be seen in Fig. 1, with data analysed in Genstat™ (Ver. 21). Regression equations for IMF% were 0.422 + 0.986 × Measured (R^2 = 0.929) and 0.937 + 0.963 × Measured (R^2 = 0.947) for uncompacted and compacted respectively, while DMD % results were -0.391 + 1.006 × Measured (R^2 = 0.879) and 0.443 + 0.994 × Measured (R^2 = 0.873), uncompacted and compacted respectively with no significant difference for either measure.

Results from this study would indicate that the compacting of dried feed and meat samples in NIR vials prior to scanning has little impact on NIRS spectra and is not necessary for accurate predictions of IMF or *in vivo* DMD.

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We gratefully acknowledge the assistance of MEQ who provided the meat samples used in this study.

Developments and concerns with the application of precision livestock management on rangelands

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Monitoring livestock health and grazing impacts on extensive rangelands is labor intensive and expensive because it is time consuming to travel throughout large pastures and often impractical or infeasible to observe all the animals. On animal sensing (OAS) has potential to remotely monitor livestock health and well-being (Bailey *et al*. 2021). Accelerometers have been successively used to determine illness and health concerns such as bovine ephemeral fever (Tobin *et al*. 2020) and mycotoxin impacts from consumption of moldy feeds (Gurule *et al*. 2022). Accelerometers and GPS tracking have been successful in detecting parturition in ewes (Fogarty *et al.* 2021, Gurule *et al*. 2021) and simulated water system failure for beef cattle (Tobin *et al*. 2021). Although these and related studies from colleagues show the promise of on-animal sensors to remotely monitor livestock well-being, additional research and technological advancements are needed before can be reliably and cost-effectively used by rangeland livestock producers. The objective of this presentation is to describe the issues associated with the development of real-time sensor monitoring and software used to detect livestock well-being concerns.

The New Mexico State University team have been involved in testing and evaluating a number of OAS over the past 4 years. Cellular-based real time tracking systems have reliably transferred cattle locations at an extensive cattle ranch (7300 ha) in central Arizona with gentle terrain and widespread Long-Term Evolution (LTE) reception. Cellular-based near real time tracking systems were also successfully in monitoring cattle movements in a mountainous ranch in southern New Mexico. The system recorded cattle positions and transmitted the positions when the cows were in an area with cellular reception. However, expected battery life was reduced by over 50% because failed efforts to transfer tracking data when the cows were not in areas with cellular reception. A real-time cattle tracking system based on Long Range Wide Area Networks (LoRaWAN) initially had transmission issues in rolling terrain. Continuing technological advancements over the past 2 years have improved the reliability of this system. A near real-time accelerometer system has also made numerous technological advances that improve its potential for remotely monitoring cattle behaviour on rangelands. Satellite based systems can overcome the issues with cellular data transmission and line of site issues of LoRaWAN systems. Data can be transferred from almost anywhere in the world. Because of the satellite data transmission costs, some satellite systems limit the frequency of transmission and summarize the data on the device to reduce expenses.

Another challenge is to detect livestock well-being concerns from real time data streams from on-animal sensors. Machine learning has been successfully used to detect behaviours and well-being concerns (e.g. Fogarty *et al*. 2021). Accelerometer data in such studies have typically been stored on the device and retrieved at the end of the study. Accelerometers often record large amounts of data from three axes at a rate of 12–25 Hz. Such data is typically condensed to epochs (often several seconds to minutes) and then paired with visual observation data. Machine learning is computationally intense and may not be appropriate for on-animal sensors. Machine learning techniques such a Random Forests can identify when behavioural patterns change. Typically, livestock activity decreases as they become ill (Tobin *et al*. 2020; Gurule *et al*. 2021). New approaches to detect behavioural change such as change point detection hold great promise. An expert-based system to detect changes in livestock behaviour is being developed and evaluated. The goal of this system is to detect changes in individual animal behaviour using recent behavioural patterns and the variability of their diurnal activity levels. For example, the hourly means of movement intensity (an accelerometer metric) would be evaluated for the last 4 days, and the standard deviation of the values could be used to quantify variability. An expert determines the type and extent of change in behaviour required to detect an outlier. Sequential outliers would then trigger notification of the livestock herdsman of a potential problem.

With ongoing improvements in data transmission, the efficacy and cost of real-time and near-real tracking and on-animal sensor monitoring should improve. Researchers should support entrepreneurs and start-up companies by using and evaluating new technologies. Collaborative teams of computer and animal scientists can develop new algorithms to detect livestock health and well-being concerns and the software interface to transfer this information in a meaningful format to ranch managers and herdsmen so they can promptly treat animals and address welfare concerns.

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Genetic benchmarking of carcase traits in Terminal sheep flocks possible with genomic testing

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The Flock Profile test has been successfully used to genetically benchmark Merino flocks (Swan *et al.* 2018). This is a crucial tool for those breeders without any knowledge of their current genetic benchmark. While the average Australian Sheep Breeding Value (ASBV) of rams purchased is often the most accurate metric, this is not always available, especially if the flock has not previously used ASBVs. At present, Flock Profile tests have only been validated in purebred Merino flocks. However, the rate of genetic gain would likely be enhanced across industry if this test were available for other breeds and in particular for commercial crossbred flocks. This study aimed to examine the predictive ability of the Flock Profile test in terminal sheep breeds as estimated from the terminal LAMBPLAN analysis.

Carcase data and genotypes were available for 14 seed stock flocks within the terminal sire analysis of LAMBPLAN. The flocks consisted of Southdown, Poll Dorset and White Suffolk breeds. To generate an independent ASBV analysis, all the phenotype data, pedigree and genotypes from these 14 flocks were removed and a special LAMBPLAN analysis was conducted. The traits analysed included carcase weight (CWT), intramuscular fat percentage (IMF), shear force at 5 days aging (SF5) and lean meat yield percentage (LMY). Using the genotypes of 20 animals randomly selected from each flock, an average ASBV (Flock Profile) was estimated using the backsolve methods described by Swan *et al.* (2018). The Flock Profile results were then compared to their true ASBV means from the full LAMBPLAN analysis using all data.

The ASBVs means and variation between flocks were similar between the full ASBV and Flock Profile results (Table 1). The predictions for CWT and LMY were highly accurate with the Flock Profile results explaining over 90% of the variation in flock mean ASBVs and also had similar levels of variation between flocks. For IMF and SF5 the predictions were not quite as accurate with the R^2 being 89.1% and 80.1%, but also underdispersed with regression slopes significantly under 1. This means that the Flock Profiles results had less variation between flocks than was present between flocks in their ASBV means and this could be due to the smaller genomic reference population for these traits.

Table 1. Relationship between flock profile results and ASBV means from the full LAMBPLAN analysis

	ASBV mean (SD)	Flock Profile mean (SD)	Slope	R^2	Correlation	RMSE
CWT (kg)	4.48 (0.92)	4.40 (0.88)	1.002 (0.093)	90.7%	0.95	0.271
IMF (%)	–0.33 (0.23)	–0.34 (0.25)	0.854 (0.086)	89.1%	0.94	0.073
SF5 (N)	2.60 (1.08)	2.57 (1.00)	0.860 (0.124)	80.1%	0.89	0.628
LMY (%)	2.42 (1.46)	2.56 (1.52)	1.039 (0.079)	93.5%	0.97	0.265

RMSE, root mean square error.

These results highlight that the Flock Profile methodology could accurately predict the ASBV benchmark within the flocks tested. However, it should be noted that unlike most commercial flocks, the flocks used in this analysis were seed stock breeders with stronger genetic links to other seed stock and research flocks in the LAMBPLAN analysis.

The longer-term challenge for the development of a commercial flock profile test for industry flocks is to accommodate their crossbred structure. Lamb production flocks generally incorporate breed components from the 3 major breed types of Merino, maternal and terminal, each of which are analysed separately by Sheep Genetics in their MERINOSELECT, Terminal LAMBPLAN and Maternal LAMBPLAN evaluations. Thus, the results would need to be expressed relative to each of these 3 different ASBV analyses. Another technical challenge is that the LAMBPLAN analyses are multi-breed, thus the genomic information is corrected for breed effects (Gurman *et al.* 2019). One of the motives of this study was to investigate this issue and ensure breeds effects could be accommodated in the Flock Profile test. This analysis should also be expanded to cover more of the traits that influence profitability in sheep enterprises such as reproduction and worm resistance. One example tool in consideration is a Flock Profile test to support the marketing of maternal replacements, allowing purchasers to value sale lots on more accurate genetic benchmarks for all the key traits rather than relying on visual appraisal alone. This initial study supports further investment into the development of these products which has the potential to offer the sheep industry another genetic tool to foster ongoing improvement in on-farm profitability.

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Comparing eutocia and dystocia: a case study using HerdDogg accelerometer ear tags

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Dystocia can cause significant impacts on cow and calf morbidity and mortality and requires close monitoring for intervention and management (Dematawena and Berger, 1997; Lombard *et al.* 2007). Monitoring calving using traditional methods, however, is a laborious and expensive task, particularly in extensive environments. As such, commercial sensor systems are becoming more readily available, with many being developed for the purposes of monitoring calving (Saint-Dizier and Chastant-Maillard 2015). This case study used a HerdDogg commercial sensor system to investigate the data from a non-calving, eutocia, and dystocia, as part of a broader study investigating calving detection using various sensor systems (Chang *et al.,* In review).

Pregnant Belmont Red (tropical *Bos taurus*) heifers were fitted with HerdDogg accelerometer ear tags (WelfareTag™, HerdDogg Inc., Wyoming, USA), which generated data that was aggregated over 6-min intervals. Accelerometer data was transmitted using Bluetooth from the ear tags to a mobile phone mounted to a 5-m structure near a watering point. Data packets were accumulated between downloading periods. The accelerometer data was summarised for each hour and a rolling mean algorithm as applied using R (R Core Team 2021).

The accelerometer data for the non-calving heifer indicates a diurnal pattern of activity, with active grazing periods occurring at dawn and in the afternoon, with a period of rest at midday and overnight (Fig. 1). For the heifer that underwent eutocia, the diurnal grazing pattern was disrupted, with moderate levels of activity displayed instead (Fig. 1). Comparatively, the heifer that experienced dystocia displayed a more prolonged disruption of the diurnal grazing pattern and a more substantial decrease in activity was observed (Fig. 1).

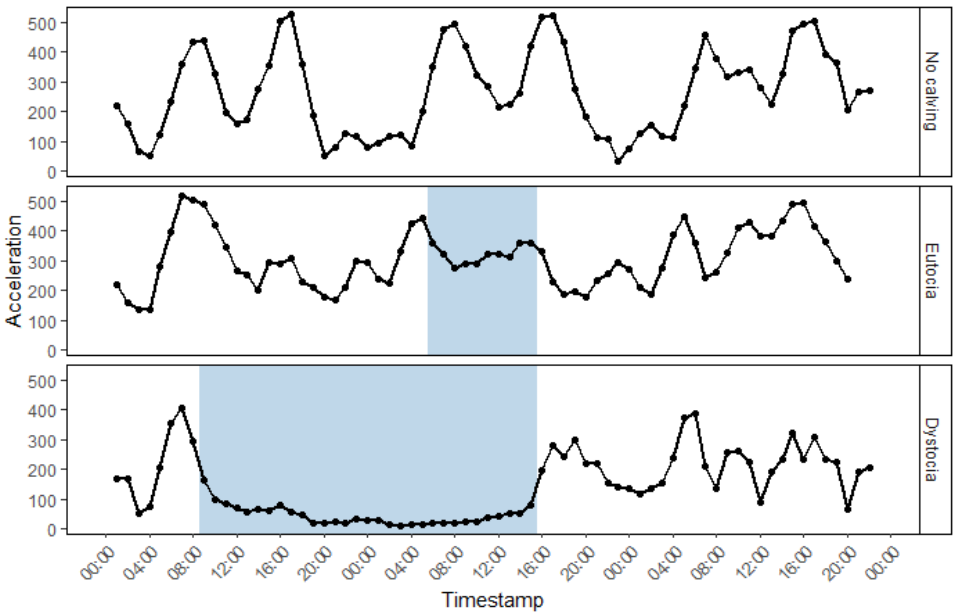

Fig. 1. Accelerometer data for a non-calving, eutocia, and eutocia. Calving periods have been shaded.

The results of this study indicate that distinctions can be made between non-calving, eutocia, and dystocia, as captured using HerdDogg ear tags, with highly distinctive reductions in activity observed in the dystocia. Both the eutocia and dystocia show deviations from the observed and expected diurnal grazing activity (Gregorini *et al*. 2006). Additional studies are required using larger sample sizes to determine the repeatability of these results for eutocia and dystocia detection.

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Proximate analysis of ryegrass when oven dried at 80°C compared with 60°C or freeze-drying

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Estimating the feeding value of forages relies on accurate dry matter (DM) determination and proximate analysis. Several drying methods are available, including freeze-drying (FD) and oven drying (OD). Prolonged OD at temperatures above 80ºC may cause thermal decomposition (Simon-Sylvestre 1975) affecting proximate analysis. Neutral detergent fibre (NDF), but not crude protein (CP) was higher when lucerne was dried at 100ºC compared with 60ºC (Jancik *et al.* 2017). Guidelines recommend drying at 100ºC for 60–90 min to arrest plant respiration following by drying at 70ºC to avoid decomposition (Reuter *et al.* 1997). Non-structural carbohydrate (NSC) content was not different when grass and legume forage samples that were dried at 100ºC for ≤1 h followed by 70ºC compared with FD (Pelletier *et al.* 2010), however, water soluble carbohydrate (WSC) was lower when ryegrass, white clover and kikuyu samples were OD at 60ºC or 80ºC for 24 h compared with FD (Fulkerson *et al.* 1998). A one-step method of drying at 80°C for 24 h offers significant advantages over current two-step methods in terms of efficiency of analysis. The dry matter (DM) content of forage and silage samples can be accurately determined by OD at 80ºC compared with 105ºC (Kaiser *et al*. 2006); however, the effect of drying at 80ºC on nutritive attributes such as CP and fibre has not previously been determined. Therefore, the aim of the current study was to determine whether proximate analysis of forage samples was significantly altered by drying at 80ºC compared with 60ºC or FD.

Fresh samples of three ryegrass varieties were dried in duplicate in an analytical oven at either 60ºC or 80ºC for 24 h or lyophilised in a freeze-dryer until reaching a constant weight. Proximate analysis was determined according to wet chemistry procedures described previously (Packer *et al*. 2011), except fat content was determined using a modified Folch procedure (Clayton *et al*. 2012). The laboratory DM content of samples was determined at the time of analysis to correct for any residual moisture after initial drying.

The proximate analysis of most parameters, including NDF, CP and WSC differed between varieties, for example CP (% DM) was significantly ($P < 0.001$) higher for variety 3 (27.80 ± 0.37) compared with variety 2 (24.87 ± 0.37) or 1 (20.05 ± 0.37). The interaction between drying method and sample was not significant, however, for any parameter (data not shown). The content of NDF was lower and CP higher when samples were OD compared with FD; however, there was no difference between OD temperatures (Table 1). The WSC content was lower when samples were dried at 60ºC compared with FD and lower again when dried at 80ºC.

Table 1. Proximate analysis of 3 varieties of ryegrass when samples were freeze dried (FD) or oven dried at either 60ºC or 80ºC showing the main effect of drying method only

	Proximate analysis (% DM)							M/D
Drying	NDF	ADF	CP	WSC	Fat	Ash	Total	(MJ/kg DM)
FD	40.03[a]	22.43[a]	21.94[b]	17.79[a]	7.15[c]	10.42[b]	97.3[b]	13.32
60ºC	37.23[b]	19.60[b]	25.46[a]	16.52[b]	8.66[b]	12.49[a]	100.4[a]	13.64
80ºC	37.70[b]	19.41[b]	25.32[a]	15.69[c]	10.34[a]	12.28[a]	101.3[a]	13.61
sem	0.17	0.27	0.37	0.17	0.33	0.16	0.60	0.11
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.003	0.139

NDF, neutral detergent fibre; ADF, acid detergent fibre; CP, crude protein; WSC, water soluble carbohydrates; M/D, metabolisable energy content of the forage (MJ/kg DM) estimated using NIR.

Further analyses should determine structural changes that lead to the lower NDF and higher CP content with OD compared with FD, as this was unexpected given previous results (Jancik *et al*. 2017). The findings of the current study indicate there is no overall adverse effect on proximate analysis drying samples at 80ºC compared with 60ºC for 24 h. Further analyses examining the proximate analysis of fresh versus frozen samples are also being undertaken.

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Variation in the amount of omega-3 in different ryegrass varieties and time of year

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The omega-3 fatty acid content of red meat is largely dependent on the amount of omega-3 consumed in the diet of sheep and cattle (Scollan *et al*. 2001). In addition, several reproduction parameters, including the sex ratio of lambs (Gulliver *et al*. 2013) and the reproductive potential of ewes (Clayton *et al*. 2017) are also influenced by the amount of omega-3 and omega-6 fatty acids consumed. The amount of omega-3 in different pasture species has been studied in detail in several countries, including Canada and the UK (Boufaied *et al*. 2003). In a survey of pastures in south east Australia, the amount of omega-3 varied across location and was related to the nitrogen content of forage (O'Keeffe *et al*. 2018). The amount of omega-3 in different species of ryegrass at different times of the growing season has not previously been investigated.

In the current study, 10 varieties of annual ryegrass (ARG) were sown in single plots on 16 April. All plots received 80 kg/Ha MAP at sowing and were harvested on five occasions. The current paper describes the analysis of five varieties of ARG; 1 = Feast II, 2 = Tetila, 3 = Hogan, 4 = Phantom, 5 = Meroa across three sampling times in early winter, late winter and spring. Triplicate samples were cut from each plot at each harvest and either dried at 80ºC for 24 h for proximate analysis or freeze-dried for the analysis of fatty acids. Crude protein (CP) was determined by the Dumas combustion method using a Leco analyser and fatty acids were determined using the one-step procedure of Lepage and Roy (1986). As plots were not replicated, differences in omega-3 content between varieties was not analysed statistically, however, standard errors were calculated across replicates for presentation. The relationship between crude protein (CP) and omega-3 content across all samples was determined using the REG procedure in SAS.

The proportion of omega-3 fatty acids was consistently higher for variety 1 (Feast II) compared with varieties 2, 3 and 5 (Fig. 1a). The omega-3 content of variety 3 (Hogan) was similar to varieties 1 and 4 in winter, but was lower in autumn and spring. The proportion of omega-3 across all samples and times was significantly ($p < 0.001$) positively correlated with the content of CP (Fig. 1b), which decreased as plants matured (data not shown). The correlation was not significantly improved when a log relationship was used (omega-3 % = 21.48 × Ln CP % – 13.98, $r^2 = 0.814$).

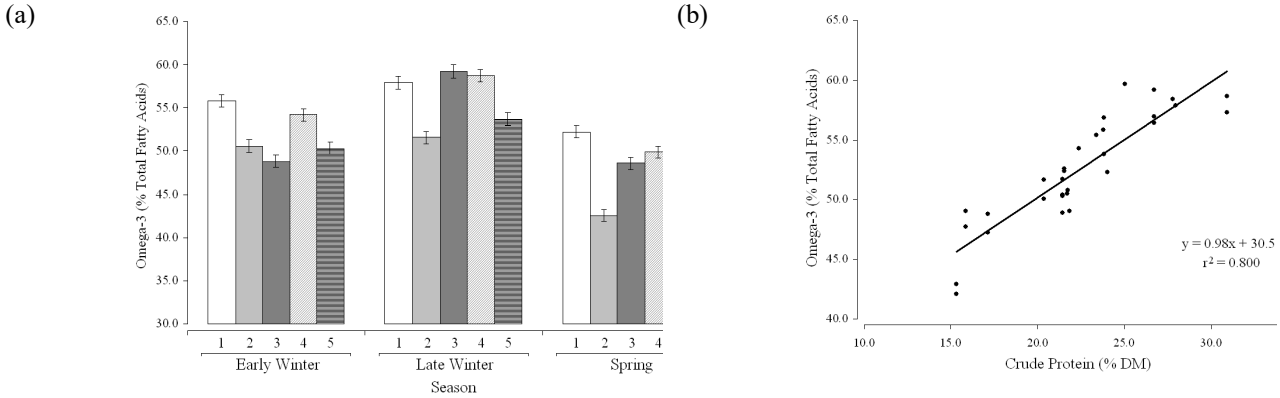

Fig. 1. Proportion of omega-3 fatty acids in 5 varieties of ryegrass at 3 different times of the year (a), and the correlation between Crude Protein content and the proportion of omega-3 (b).

The range in values observed for individual varieties demonstrates the need for further investigation into the level of omega-3 using replicated plot trials across different stages of growth. Of particular interest would be to determine whether varieties of ryegrass could be bred specifically for higher omega-3 content at different times of the year and whether the omega-3 content of beef and lamb can be manipulated by the incorporation of these forages into the ration of cattle and sheep throughout the year.

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Automatic assessment of lamb liver health status using hyperspectral imaging

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Automation of the offal sortation process according to animal health defects and fitness for human consumption could reduce cost and improve accuracy in the abattoir. Currently, meat inspectors under the supervision of a veterinarian take on this process (Webber *et al*. 2012). Automation has occurred in abattoirs to provide information about carcass yield and quality at chain speed (Scholz *et al*. 2015). Hyperspectral (HS) imaging including visible (VIS) and short-wave infrared (SWIR) wavelengths has been successfully trialled in food quality and safety studies (Huang *et al*. 2014). In the present study, we aim to use VIS and SWIR HS imaging to differentiate lamb livers that passed or failed to pass fitness for human consumption following veterinary examination.

Twenty-four lamb livers, randomly sampled from a collaborating abattoir, were scanned using an HS system (AK198, Rapiscan Systems, Torrance, CA) fitted with VIS (400 to 900 nm; Basler GigE) and SWIR (900 to 1700 nm; Snake A/C GigE) HS cameras (Photonic Science, East Sussex, UK) and a conveyor passing samples under both cameras at 189.8 mm/s. Following scanning, veterinary pathologists recorded gross lesions present (diseased, n = 11) or absent (healthy, n = 13). The liver lesions (diseased group) included focal parenchymal mineralisation (4), appearance defects (2), chronic hepatitis, hepatic capsular haemorrhage, capsular fibrosis, caseous lymphadenitis and abscess formation. The gross diagnosis of the lesions was corroborated by histopathological examination. Images generated were marked-up for eight regions of interest (ROI) of 7 × 7 pixels using ImageJ software. Reflectance spectra were extracted from each ROI using GIMP software and a MATLAB algorithm. Three datasets (VIS, SWIR and combined) were used to develop classification models in RStudio using the mean absorbance of the ROI. Models were developed using three classification methods within the *Caret* package (Kuhn 2020): partial least squares discriminant analysis (PLS-DA), linear discriminant analysis (LDA) and random forest (RF). Model goodness of fit was assessed using resampling with leave-one-out cross-validation.

Table 1 shows the fit statistics for the three classification methods and three spectral datasets compared for their ability to discriminate healthy and diseased lamb livers. Depending on the method used, the individual HS sensors outperformed the combined VIS-SWIR dataset and with high accuracy (>75%) and precision (≥80%).

Table 1. Model statistics showing the ability to discriminate healthy and diseased lamb livers

Sensor/method	n[A]	Diseased	Healthy	logLoss	AUC	Sensitivity	Specificity	Precision	Accuracy	Kappa
Visible										
PLS-DA	8	11	13	0.658	0.769	0.727	0.615	0.615	0.671*	0.338
LDA	–	10	14	1.533	0.587	0.636	0.538	0.538	0.587*	0.172
RF	20	11	13	0.661	0.721	0.727	0.846	0.800	0.792	0.577
SWIR										
PLS-DA	6	11	13	0.563	0.769	0.818	0.692	0.692	0.755*	0.503
LDA	–	11	13	0.386	0.902	0.818	0.846	0.818	0.833	0.664
RF	70	11	13	0.755	0.545	0.454	0.692	0.556	0.583	0.149
Combined										
PLS-DA	12	11	13	0.652	0.790	0.727	0.692	0.667	0.710*	0.417
LDA	–	11	13	1.753	0.517	0.455	0.538	0.455	0.500	-0.007
RF	2	11	13	0.586	0.745	0.545	0.769	0.667	0.667	0.319

[A]n: number of components used (PLS-DA) or variables tried (RF). *: balanced accuracy was used. AUC: area under the curve. VIS: Visible. PLS-DA: partial least squares discriminant analysis. LDA: linear discriminant analysis. RF: random forest.

Interestingly, each dataset showed the highest precision, accuracy, and coefficient of agreement (Kappa) with a different classification method. Combination of the two cameras showed the greatest accuracy using PLS-DA, VIS using RF, and SWIR using LDA. The greater classification accuracy in SWIR compared to VIS has been found in most studies on animal products (Huang *et al*. 2014), suggesting that one camera could be better and more cost effective than two. Overall, the encouraging results from the present study suggest that a larger study using greater numbers of livers and other organs is necessary to determine the optimal wavelength ranges for differentiating healthy and diseased organs, with eventual use in an abattoir setting.

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Breath biomarkers for volatile fatty acids and microbial populations in the rumen

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Current methodologies used to access rumen fluid are invasive. Consequently, there is a need for a non-invasive methodology to measure volatile fatty acid (VFA) production and other biomarkers to evaluate *in vivo* ruminal fermentation. In this study, the use of breath VFAs to estimate total VFA production was assessed and compared with VFAs determined by invasive collection methods (rumenocentesis and oral stomach tube). The impact of different diets on VFA levels was also evaluated using three sampling methods (rumenocentesis, oral stomach tube and breath testing). Additionally, the impact of rumenocentesis and oral stomach tube methods on microbial populations was assessed. Forty Merino ewes (initial live weight = 57.3 ± 5.8 kg, mean ± standard deviation; 24 months of age) were housed in individual pens for a total of 51 days. Ewes were acclimatised over a 16-d period and fed a high grain-based diet (70% grain and 30% roughage) or a roughage-based diet (100% roughage) for 35 days. On day 51 of the feeding period, two breath samples were collected from each ewe 3h post-feeding, followed by percutaneous needle aspiration (rumenocentesis) and ruminal extraction (oral stomach tubing) to collect rumen fluid. Microbial analysis of samples collected from both invasive methods was performed and a Wilcoxon rank-sum exact test was conducted on Faith's phylogenetic diversity to compare the two diets and two methods of collection. Breath gas VFAs absorbed onto triple bed sorbent tubes were thermally desorbed and analysed using gas chromatography-mass spectrometry. All data of exhaled breath and rumen fluid were analysed using SPSS, fitting a univariate general linear model and calculating correlations between all methods where a probability less than 0.05 was considered significant.

Table 1. Volatile fatty acid concentration proportions for all treatments (mean ± standard deviation)

Acids	Rumenocentesis		Oral stomach tube		Breath		SEM	*P*-value		
	Grain	Roughage	Grain	Roughage	Grain	Roughage		Diet	Method	Diet × Method
Acetic (%)	54.99 ±4.95	57.92 ±4.01	56.20 ±5.18	57.25 ±4.25	81.51 ±12.30	83.90 ±9.79	0.19	0.16	<0.01	0.84
Propionic (%)	32.45 ±5.29	26.93 ±2.04	31.18 ±5.55	26.55 ±2.78	12.93 ±9.85	10.96 ±7.32	0.91	<0.01	<0.01	0.45
Butyric (%)	12.56 ±3.13	15.16 ±3.20	12.61 ±3.30	16.19 ±3.28	5.56 ±3.35	5.14 ±2.76	1.92	0.03	<0.01	<0.01

Acetic acid had the highest concentration observed across all methods, followed by propionic acid and butyric acid. There was no interaction between diets and methods for acetic acid and propionic acid proportions, however, a significant interaction between diet and methods was observed for butyric acid proportions ($P < 0.01$; Table 1). There was a significant difference between methods for acetic and propionic acids ($P < 0.01$). The proportion of acetic acid was greater in breath samples (82.9%) in comparison with rumen fluid samples collected by rumenocentesis (56.4%) and oral stomach tube (56.7%). On the other hand, the proportion of propionic acid was lower in breath samples (11.8%) in comparison with rumen fluid samples collected by rumenocentesis (29.9%) and oral stomach tube (28.9%). The differences observed could be explained by the sorbent tubes used to collect breath samples, since higher losses of VFAs were observed when stainless steel sorbent tubes were used (Kim and Kim 2013). There was a significant difference in propionic acid proportions between diets ($P < 0.01$). The proportion of propionic acid in ewes fed high grain-based diet was greater than in ewes fed the roughage-based diet (26.7% vs. 21.5%; $P < 0.01$). There were no significant correlations between breath VFA (acetic, propionic and butyric acids) proportions and either invasive method, although there was a strong correlation of acetic acid (r = 0.96), propionic acid (r = 0.98) and butyric acid (r = 0.98) proportions between rumenocentesis and oral stomach tube methods ($P < 0.01$). For all rumen fluid samples, the microbial population diversity differed between diets ($P < 0.01$); however, no difference was detected between oral stomach tube and rumenocentesis methods. The strong correlation observed between invasive methods confirms that both methods give comparable VFA concentrations. In conclusion, current breath testing to measure VFAs is not consistent with results obtained from invasive collection methods and more research and development is required.

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Intestinal gene expression profile in free-range laying hens with divergent behaviour and body weight

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Investigating the time budgets of free-range laying hens have recently found associations between range use and production traits, including egg laying performance and body weight (Sibanda *et al.* 2020). Differences in range usage of hens in free-range systems reflect particular preferences and behaviours where some hens will spend more time in outdoor areas ('rangers') while others will stay inside the sheds ('stayers'). We hypothesised that different biological processes take place in these hens based on their range use or body weight. Therefore, the aim of this study was to describe the gene expression profile in jejunal tissue obtained from ranger and stayer hens with divergent body weight using RNA sequencing.

Three flocks of 40,000 hens were recruited into the study. A subset of 3125 hens per flock was randomly identified at 16 weeks of age. These animals were monitored until 72 weeks of age with a custom-made RFID system (Sibanda *et al*. 2020). At 74 weeks, 32 hens were selected based on the range usage ('stayers', who spent 20% of their available time on the range and 'rangers' who spent 75% of their available time on the range) and body weight ('heavy' hens weighing > 1.90 kg and 'light' hens weighing < 1.75 kg). Four groups with eight samples each were selected without considering the flock variable. These groups were analysed based on their range usage and body weight: rangers-heavy (RH), rangers-light (RL), stayers-heavy (SH), and stayers-light (SL). A differential expression analysis was performed using six contrasts: RHvsRL, RHvsSL, RHvsSH, RLvsSL, and SHvsSL. Jejunal tissue was obtained from each hen and preserved in RNAlater at –20°C. RNA was extracted with TRIsure TM and purified using ISOLATE II RNA Mini Kit (Bioline) following manufacture instructions including the elimination of genomic DNA. We ensured that all the RNA samples were of high quality (RNA integrity number > 8) using the RNA 6000 Nano Kit (Agilent Technologies, Inc., Waldronn, Germany) and Bioanalyzer (Agilent Technologies, Waldbronn, Germany). Complementary DNA libraries were synthesised and then sequenced by Australian Genome Research Facility Ltd with Illumina HiSeq 2000 platform obtaining100 bp paired-end reads. A standard bioinformatics pipeline included a quality assessment of the RNA sequences done with FASTQC v0.11.5 while Trimmomatic was used to clean the reads. These reads were mapped to the chicken reference genome (*Gallus gallus*; WASHUC2) and assembled using HTSeq v0.6.1. The gene count matrix was normalised with the trimmed mean of M-values normalisation (TMM) in edgeR v3.28.1. Genes were considered differentially expressed between the groups based on the adjusted p-value (FDR < 0.05) and the absolute logarithm 2-fold change ($\left|\log2FC\right| > 1$).

After a quality assessment, seven samples were removed due to low mapping rate (<80%), low library size or for outlier gene expression profile, resulting in 25 samples used for the analysis (RH = 7, RL = 5, SH = 8, and SL = 5). Out of the 12,472 expressed genes in the dataset, there were 151 differentially expressed genes (DEG) from the contrast SHvsSL (DEG: 1), RHvsSL (DEG: 3), RHvsRL (DEG: 3), RLvsSH (DEG: 11), and RLvsSL (DEG: 133). However, there were no differences in gene expression for the contrast RHvsSH. The top 10 differentially expressed genes were observed in RLvsSL: *CXCL13L2*, *VPREB3*, and *ENSGALG00000010336*; RHvsRL: *MYO16*, *ENSGALG00000004862, SGK1; RLvsSH: AVPR1B*, *FAXDC2*, and *MYO16*; SHvsSL: *MLKL*; RHvsSL: *ADGRG2*, *ENSGALG00000003949*, and *ENSGALG00000005671*. These DEGs have important functions related to immune response and feed efficiency. The *CXCL13L2* gene was previously found enriched during stress-induced immunosuppression in Gushi cocks (Guo *et al*. 2020). A possible role in the maturation and secretion of immunoglobulin light chain in B-cells was suggested to be actioned by the *VPREB3* gene product (Rosnet *et al*. 2004). The *MYO16* gene was upregulated in jejunum of Korat chickens with a low feed conversion ratio (Sinpru *et al*. 2021). Another DEG *FAXDC2* was differentially expressed between chickens with low and high residual feed intake (Yi *et al*. 2015). Both, *MLKL* and *FAXDC2* genes were downregulated in chickens challenged with necrotic enteritis (Gharib-Naseri *et al*. 2021).

In conclusion, our study provides an insight on the gene expression profile of laying hens with particular behaviour and body weight, which showed larger differences in rangers-light vs stayers-light contrast. Differentially expressed genes are suggested to be involved in the body weight, but the expression of some DEG may be also related to an immune response to pathogens found outside the shed. Further research should consider other tissues (i.e. brain) to investigate the impact of differential gene expression on the hens' behaviour.

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Pilot study on plasma markers of energy balance in pregnant sheep on farm

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The energy demands associated with pregnancy and lactation can lead to negative energy balance and metabolic diseases such as pregnancy toxaemia in ruminants. Energy demands can be especially great for animals carrying multiple foetuses, as is common in smaller ruminants. Plasma ketones (e.g. β-hydroxybutyrate; BHB) are useful markers of energy balance and can be measured on the spot using hand-held meters. While many studies have examined markers of energy balance in dairy ruminants, limited data exists for commercial meat sheep breeds in on-farm conditions. The aim of this study was to gather preliminary data of some key plasma markers of energy balance using a combination of on farm and laboratory measures in commercial meat sheep.

This experiment was conducted on a sheep farm in Northern Victoria (Pepperton Farms, Elmore Vic.) and approved by the Faculty of Veterinary and Agricultural Sciences (University of Melbourne) animal ethics committee. Female sheep (76 Dorsets and 13 White Suffolks, 1–5 years) were selected. Sheep were synchronised with Regulin (Ceva Animal Health, NSW, Australia) then artificially inseminated 2 weeks later. Pregnancy was confirmed via ultrasound 68 days after insemination and sheep with either single (n = 50) or multiple (2: n = 37 and 3: n = 2) lambs were selected. Sheep were managed as per standard farm practices. On days 68 and 145 of gestation blood samples were obtained via jugular venepuncture. Samples were immediately assessed for whole blood glucose (AccuChek, Roche, NSW, Australia) and BHB (FreeStyle Optimum, Abbott Diabetes Care Ltd., UK) using hand-held meters, then plasma was isolated via centrifugation and stored at –20°C. Analysis of plasma urea nitrogen (PUN, Infinity Urea Liquid Stable Reagent, Thermo Fisher Scientific (TFS), Waltham, MA), urea (Infinity Urea Liquid Stable Reagent, TFS) and plasma non-esterified fatty acids (NEFA; NEFA-C ACS-ACOD, Wako Pure Chemical Industries Ltd., Osaka, Japan (modified as per Johnston and Peters (1993)) were undertaken. Data was log transformed prior to analysis (presented as back-transformed data) and analysed using the restricted maximum likelihood (REML) function for repeated measures in Genstat (v.19) with the main factors of day of gestation, number of lambs (1 vs 2+) and their interactions, with the random factor of sheep ID. Breed and parity did not significantly impact any variables and were excluded from the final model.

Mean plasma metabolite data is presented in Table 1. The maximum BHB value recorded was 1.2 and 1.4 mmol/L (single and multiple lambs respectively, n = 1 sheep each). There were 14 samples ≥0.8mmol/L BHB, from a mix of single and multiple pregnancies and all observed at 145 days. All glucose values recorded were within normal ranges.

Table 1. Mean metabolite concentrations of ewes bearing single or multiple lambs at 68 and 145 days gestation[A]

Gestation day (G)	68		145			*P*-values		
Number of lambs (N)	Single	Multi.	Single	Multi.	SED	G	N	G × N
Glucose (mmol/L)	3.5	3.5	3.8	3.6	1.03	0.001	0.360	0.077
BHB (mmol/L)	0.2	0.3	0.4	0.5	1.08	<0.001	0.002	0.669
PUN (mg/dL)	47.4	48.8	51.3	51.9	1.01	<0.001	0.034	0.406
NEFA (μM)	873.0	1069.1	588.8	612.4	1.08	<0.001	0.012	0.116
Urea (mmol/L)	2.8	2.9	3.1	3.1	1.01	<0.001	0.034	0.406

[A]Values are back-transformed least-square means, standard error of differences (SED) and *P*-value from linear mixed effects model accounting for repeated measures. BHB, β-hydroxybutyrate. PUN, plasma urea nitrogen. NEFA, non-esterified fatty acids.

This study demonstrated that all plasma metabolites measured increased (except for NEFA) in late gestation compared to mid gestation, and all increased in ewes carrying multiple lambs. This is expected as tissue stores of energy are mobilised to support the pregnancy and prepare for lactation. The high NEFA values measured on day 68 are likely driven by stress given the sheep were handled for a longer period while pregnancy tested. The increase in plasma glucose is surprising and is perhaps driven by the gestation date being so close to parturition (expected day 147). The presence of multiple lambs also marginally increased mobilization of energy stores. As BHB (and to a lesser degree glucose) measured on-farm followed the same trend as other markers of energy balance measured in the laboratory, the hand-held meters are potentially a useful tool for on-farm animal screening. Further analysis will be undertaken to determine relationships between metabolites and if animals ranked consistently in plasma marker thresholds. Although in this experiment few sheep exceeded the accepted 0.8 mmol/L threshold that dictates toxaemia (Andrews 1997). This pilot data will form the basis of future studies to assess if these markers are related to subsequent pregnancy toxaemia cases in commercial sheep.

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Using natural abundance of nitrogen isotopes to identify more efficient cows in northern Australia

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Cows grazing rangelands in northern Australia are often reliant on low-quality pasture during late gestation and early lactation. To successfully wean a calf and get in calf again cows need to be able to maintain their body condition score (BCS) while lactating. The natural abundance of ^{15}N in body protein reflects the amount of Nitrogen (N) that is being retained in the body due to the nature of preferential incorporation of ^{14}N into protein thus more animals that are more efficient at retaining N will have a lower proportion of ^{15}N on the tail hair than less efficient animals. This is particularly important when cattle are on low protein diets such as the dry season in northern Australia and small differences in efficiency of N retention can be the difference between maintenance and loss of BCS. The hypothesis was that cows that produce and wean a calf every year will have lower ^{15}N in tail hair than cows that do not wean a calf every year.

This study was conducted at Burleigh Station, Richmond region, Queensland and was approved by The University of Queensland Animal Ethics Committee and the University of New England Animal Ethics Committee. Approximately 630 Brahman and Brahman cross cows and heifers were divided into low- or high-efficiency sub-groups based on reproductive performance over four musters during 2017 and 2018.The reproduction efficiency index was based on a point system where 1 point was given for pregnancy and for lactation at each muster, each cow could have a maximum of 8 points. Within the herd the cows assigned to the high efficiency subgroup had a mean index of 4.88 (max 6.0, min 4.0) and the cows assigned to the low efficiency had a mean index of 2.81 (max 4.0, min 1.3). The reproductive performance index only considered the number of successful pregnancies and calves weaned (based on pregnancy and lactation status at each muster) the index did not take into account weight of calf weaned or age of dam.

Tail hairs were collected from 23 animals in each subgroup and cut into seven sequential 20 mm segments. Tail hair was processed to remove contaminants as per Schwertl *et al.* (2003) then isotope ratio measurements performed using an IsoPrime100 isotope-ratio mass spectrometer (Isoprime Ltd, Cheadle, UK). Stable isotope values from tail hair segments were analysed as a complete randomised design with repeated measures in time with subgroup (low or high efficiency) as a fixed effect (SAS v.9.4).

Cows that were assigned to the high efficiency subgroup had significantly ($P < 0.05$) lower ^{15}N concentrations over the drier months (November 2018 to February 2019 and May 2019) than cows assigned to the low efficiency subgroup. There was a large rain event in February 2019, which improved pasture quality, and this was reflected in the isotope profile of the tail hair (Fig. 1).

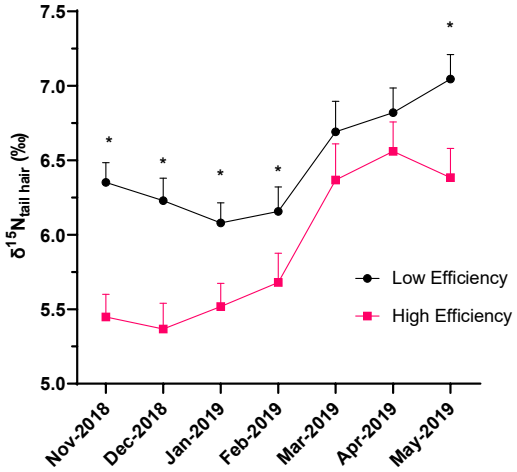

Fig. 1. Variation in $\delta^{15}N$ concentration on tail hair segments over the dry season in cows selected for low or high efficiency.

In conclusion, this study showed that ^{15}N concentration in tail hair during dry periods when pasture N concentration was low was correlated with reproductive efficiency in cows. This indicates that a lower proportion of ^{15}N was associated with cows displaying a greater propensity to pregnancy and lactation indicating increased calf survival. Analysis of N isotopes on tail hair could be used as an indicator of predicted individual reproductive performance of cows grazing low N pastures.

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The use of hypobaric chambers for ageing lamb loins

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Consumer demand is increasing for premium imported lamb in wet markets as factors such as greater disposable incomes and urbanisation drive higher consumption of lamb products. As consumer demands increase, methods for export complimentary to live export will be required to ensure demand can be met. Improvements in hypobaric chamber technologies have resulted in the use of such vacuum chambers to transport perishables (Jiao *et al*. 2012). Previous work indicated that purge loss was greater for lamb loins when aged in hypobaric chambers compared to ageing in a chiller vacuum packed (Fowler *et al*. 2016), but the effect on tenderness has not been reported. This paper outlines the impact on tenderness of lamb loins stored in hypobaric chambers compared to loins stored vacuum packed in a chiller for 5 weeks as a preliminary study, with a final focus on transportation of whole carcases to meet the demand for specific religious occasions particularly in the Middle East, given the demand for home preparation.

The left and right loins from 24 lamb carcases were collected 24 h post-mortem. Loins were then weighed and assigned to one of three treatment groups; vacuum packaged (control), CO_2 hypobaric chamber and air hypobaric chamber. Samples from the left and right side of three carcases were randomly assigned to treatment groups so that the left and right sides of one carcase were assigned to air and CO_2 treatment groups, another left and right loin from the second carcase were allocated to air and control and loins from a third carcase were allocated to CO_2 and control treatment groups. This was repeated 3 times within each run (replicate; $n = 72$).

After 5 weeks storage in the treatments at 0°C, the loins were removed. All shear force blocks were held frozen (at –22°C) until analysis. Determination of shear force values was conducted using shear force blocks (mean weight = 66 g ± s.d. = 2.55 g) cooked at 71°C for 35 min and analysed using a Lloyd texture analyser with a vee-blade as described by Hopkins *et al.* (2010) on 6 replicates per shear force block. Where the co-efficient of variation exceeded 24% for the six replications, the median of the values was reported rather than the average of the six repetitions (Hopkins *et al*. 2012). REML (Genstat ed. 18) mixed models with replication, chamber and side of the carcase as random effects were used to determine if a significant difference between treatments was present for meat quality traits.

Analysis of shear force values demonstrated that ageing was significant ($F_{1,6} = 213.07$; $P < 0.001$), average shear force values at day 1 (67.9 N) being higher than the average shear force values after 35 days storage (27.4 N). However, there was no effect of treatment in the hypobaric chambers and no interaction between ageing and treatment in the hypobaric chambers (treatment $F_{2,4} = 3.31$; $P = 0.142$, interaction $F_{2,6} = 0.32$; $P = 0.736$).

The results demonstrated that the improvement in tenderness through ageing in a hypobaric chamber was equivalent to the improvement attributable to ageing in a vacuum pack as there was no significant difference in the mean shear force values for the treatment groups and the control group after 35 days. With the target on the transportation of whole carcases, this finding provides confidence that whole sheep carcases could be transported or stored using hypobaric storage methods and be effectively aged while in transit. Further development of this concept and subsequent commercialisation involving the development of hypobaric shipping containers specifically for the transport of chilled sheep carcases would open up opportunities for transport of whole chilled sheep carcases directly into wet markets in countries around the world, but particularly into the Middle East. The use of such systems is not seen as replacing live exports but complementing the live export trade through expansion of the total value of the live sheep and sheep meat market to those countries. It would also provide the ability to service markets Australian live exporters are not permitted to send live sheep to due to animal welfare concerns.

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Prediction of intramuscular fat content of lamb loin using spectra from the topside

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Given the paucity of lamb carcase grading tools, there is a distinct need and interest from industry for the development of rapid, non-destructive grading tools for Australian lamb carcases, particularly for intramuscular fat content (IMF) due to its importance to meat and eating quality (Hopkins *et al*. 2006). However, the development of such methods for commercial processors in Australia is challenging as lamb carcases are not split or quartered prior to the breakdown of the carcase into saleable meat. Therefore, research was completed to determine the potential for near infra-red spectra (NIR) collected from the topside pre-rigor to predict the IMF content of lamb loins.

NIR spectra were collected from 116 topsides at 25 min post-mortem *in situ* with the subcutaneous fat removed prior to measurement on Merino lamb carcases over 3 measurement periods (kills). An ASD® TerraSpec4 high resolution spectrometer with the ASD® contact probe attached via a fibre optic cable was used. At 24 h post-mortem, the left M. *longissimus lumborum* (loin) was collected and a portion was analysed for IMF content using a modified AOAC (1992) method. Spectra were converted from transmittance to absorbance and averaged by carcase, before splice correction was completed at 1000 nm and 1800 nm with a linear interpolation of five bands. Spectra were then corrected using the continuum removal method and the optimal number of latent variables were established before Partial Least Squares models were run using leave one out cross validation methods (Kucheryavskiy 2020).

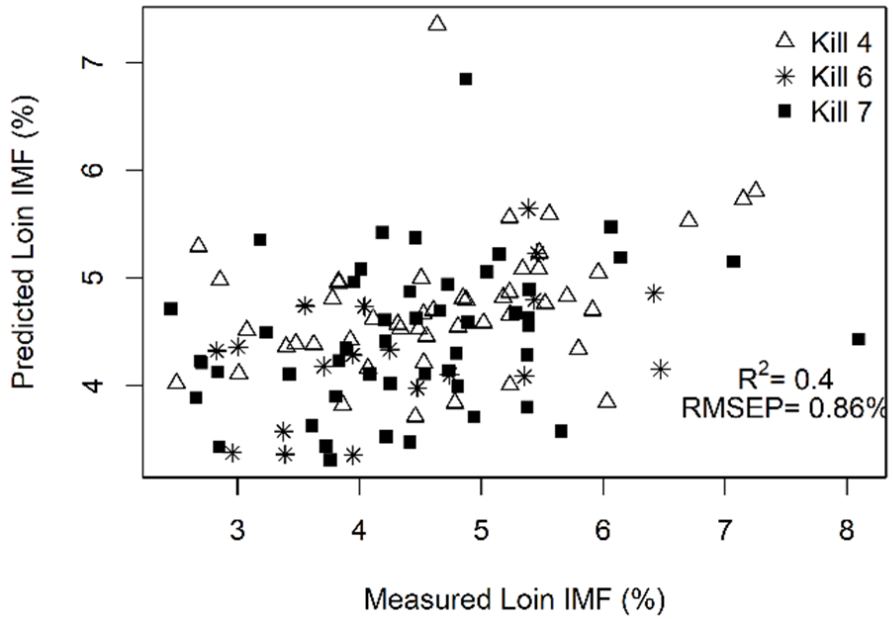

Fig. 1. Prediction of the loin IMF content using NIR spectra collected from the topside.

Prediction of the loin IMF content using the topside spectra gave a model with a R^2 of 0.40 between the predicted loin IMF and measured loin IMF and an error of RMSEP = 0.85% using five components (Fig. 1).

Previous research suggests the accuracy is higher than would be expected from spectra collected early post-mortem as spectra collected at a similar time yielded a lower accuracy (R^2 = 0.27) (Alvarenga *et al*. 2021). However, the accuracy found is closer to that of the topsides that had progressed further towards rigor, suggesting the pH decline of the topsides in the current study may have differed to previous studies resulting in more accurate models from pre-rigor spectra. Yet it is not possible to determine based on the data from this study as temperature and pH decline were not measured. Therefore, investigation of pH decline and temperature on the outcomes of NIR models is required, given they varies between processors, kills and lots.

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Use of an Optiweigh to monitor mob and individual weight gains in feedlot pens

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Monitoring weight gains in feedlot cattle using a crush is time consuming and may impact cattle performance through increased handling and time spent away from the pen. Methods for in pen weighing around a water point in feedlots have been developed (Vytelle 2022) but there may be opportunity to use other more portable systems in feedlot pens. The Optiweigh system (Optiweigh 2022) has been developed for in paddock weighing of cattle using a stand-alone unit with a supplement block as an attractant and satellite-based telemetry for data communication. When cattle access the supplement in the Optiweigh, by placing their front feet on a platform, a partial body weight is recorded and converted to a full body weight. This project used an Optiweigh in a feedlot pen to determine whether feedlot cattle would utilise it when a complete diet was already on offer and if it could be used to accurately monitor weight gain over a feeding period.

This study was conducted at the UNE SMART Farms Tullimba feedlot. Two cohorts of heifers (n = 32 and n = 34, average start weights 344.2 kg and 397.5 kg, respectively) were fed a typical shortfed domestic market (~80 days) feedlot ration once-daily in small open-bunk pens (12.5m x 40m) with a single water trough per pen. From the first day of feeding, an Optiweigh with a high molasses mineral lick block as the attractant was continuously available in the pen. Cattle were taken to the yards and weighed in the crush on day 1, at 3-weekly intervals and on exit to allow comparison to the Optiweigh recorded weights. Time taken for cattle to first access the Optiweigh and the overall pattern of access were also assessed.

Optiweigh and crush weights were highly correlated (P <0.001) for cohorts 1 and 2 (R^2 = 0.89 and 0.93, respectively) with a root mean square error (RMSE) of ±12.53kg/head for cohort 1 and ±12.23kg/head for cohort 2. All animals in both cohorts accessed the Optiweigh during the feeding period, with half the animals accessing it within four days and 95% within two weeks (Table 1). The mean total number of visits by an individual animal to the Optiweigh varied between the two cohorts (Table 1) with more visits in cohort 2 than cohort 1. On a mob and individual basis, however, there was large variation between individuals and across days within both cohorts.

Table 1. Use of the Optiweigh over a feeding period for two cohorts of cattle

	Cohort 1	Cohort 2
Days taken for animals to use the Optiweigh		
50% of heifers	2	4
75% of heifers	4	5
95% of heifers	13	10
100% of heifers	71	21
Mean total no. of visits/individual over the feeding period[A]	145.6 ± 76.3	265.6 ± 114.9
Mean no. of visits/day for individual[1]	2.9 ± 0.71	3.9 ± 1.31
Mean no. of visits/day for the group[1]	60.2 ± 21.9	95.5 ± 44.6

[A]Values are means ± standard deviation.

Body weight predicted by the Optiweigh was highly correlated with crush weight and provided a good daily indicator of liveweight. The majority of animals used the Optiweigh within a week and 95% within two weeks indicating that an Optiweigh could be used at strategic time points or for short periods during a feeding to assess weight and weight gains on both a mob and individual basis, enabling a single unit to be moved between pens to monitor multiple cohorts simultaneously. This study used small pens and groups, so animals had plenty of opportunity to access the Optiweigh. More units may be necessary for larger commercial situations to allow ample access to the Optiweigh by all animals within a group. Although developed for paddock use, these results indicate that the Optiweigh has potential for use in feedlot situations for monitoring weight and weight gain reducing the handling required for regular crush weighing during a feeding period.

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Home pressure cookers can be used to estimate neutral and acid detergent fibre content of forage

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Neutral and acid detergent fibre (NDF, ADF) are critical traits that are used to predict the performance of ruminants grazing forage. While the chemical principles for the analysis of detergent fibres have remained constant (Van Soest and Robertson 1980), the methodology has evolved (Van Soest 1994). The major changes have included moving away from boiling material in beakers and filtering, towards incubating material in sealed filter bags in pressurised containers. The ANKOM method (ANKOM Technology, Fairport, NY, USA) uses samples sealed in filter bags with digestion with reagents in a pressurized vessel. This method requires the machine, filter bags, reagents and electricity, factors that are not always available in developing or conflicted countries. In this study, we investigated the use of an inexpensive home-kitchen stainless steel pressure cooker (that can be heated with an electric or gas hotplate) as an alternative to the electric ANKOM fibre analyser. We tested the hypothesis that analysis using the pressure cooker would allow for estimation of NDF and ADF content. The aim was to quantify the accuracy and precision of the pressure cooker method.

Eight diverse forage samples were dried at 60 ºC and ground through a 1 mm screen. For each forage, 18 × 0.5 g samples were weighed to four decimal places into ANKOM F57 fibre bags, with samples split into three runs of three replicate samples for each method. The sample bags were used for sequential NDF, followed by ADF. Both analysis methods utilised the standard NDF and ADF solutions (ANKOM 2020). The ANKOM method used the ANKOM 200/220 Fiber Analyzer according to operating instructions. For each pressure cooker run, the same volume of NDF solution was poured over the bags, the lid was secured, and the cooker was placed on an electric hot plate. It was heated to 100ºC and refluxed for 75 min. Pressure was carefully released from the vessel and the bags removed with tongs and placed into a 5 L jar with a vented lid. For rinsing (both methods), 2 L of water at ~90°C was added to the jar and gently swirled for 2 min before decanting into a colander in a sink. This was done four times. After the final rinse the bags were removed, excess moisture was pressed out gently with paper towel, and the bags were dried an oven set at 90ºC for 24 h. Protective gloves and safety glasses should be worn, and the reflux solution should be cooled before decanting. Bags were put into a desiccator and then weighed to determine NDF on a DM basis. The same protocol was followed for ADF on the same samples, except the reflux time was reduced to 1 h at 100ºC and the ADF solution was used.

Table 1. ANOVA comparing the means of 3 runs (each mean calculated from 3 replicate samples within a run) and the means of standard errors (calculated from 3 samples within a run) for NDF and ADF measured using an Ankom Fibre analyser or a pressure cooker

Sample	NDF						ADF					
	ANKOM			Pressure cooker			ANKOM			Pressure cooker		
	Mean		Mean SE	Mean		Mean SE	Mean		Mean SE	Mean		Mean SE
Oldman saltbush	30.5	a*	0.63	31.5	a	1.17	16.3	a	0.20	16.2	a	0.51
River saltbush	33.5	b	0.50	33.1	a	1.37	18.6	b	0.20	18.0	b	0.57
Creeping saltbush	46.5	c	0.96	46.8	b	0.84	27.1	c	0.58	26.0	c	0.64
Rhodes grass	65.3	d	0.26	66.0	c	0.67	32.2	d	0.18	32.1	d	0.28
Oaten hay	59.9	e	0.43	58.6	d	0.62	32.5	d	0.25	31.6	d	0.34
Clover/grass	57.6	f	0.64	58.4	d	1.04	35.3	e	0.30	35.6	e	0.96
Temperate grass	69.1	g	0.58	68.6	e	1.08	36.7	f	0.29	36.4	ef	0.52
Tropical grass	66.4	d	0.47	65.2	c	0.66	38.1	g	0.30	37.8	f	0.41
SED	0.6			1.1			0.5			0.6		
LSD (5%)	1.39			2.40			1.10			1.40		
P value	<0.001			<0.001			<0.001			<0.001		

*Means with the same letter within columns are not significantly different.

There were no differences associated with between-run consistency for both methods. The methods gave very similar mean values and when means for each run were regressed by method, the percentage variance accounted for was 97.9 ($P < 0.001$) for NDF and 96.4 for ADF ($P < 0.001$, regression data not presented). The pressure cooker method resulted in standard errors that were approximately twice as large as the standard errors for the ANKOM method ($P < 0.05$). The increased variability in the pressure cooker method led to detection of fewer significant differences in fibre content between the forages (Table 1). In conclusion, the pressure cooker method was suitable to accurately determine NDF and ADF, but the precision was lower. Precision may be overcome through increased replication. The method has potential for use in developing and conflicted countries where expensive equipment and a stable supply of electricity are challenges.

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Validation of temperature classification using remote-sensing technology during oestrous synchrony in Merino ewes

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Remote-sensing technology facilitates longitudinal collection of body temperature, providing an opportunity to better understand the physiological thresholds of extensively grazed livestock throughout a changing climate. Core temperature is one of the primary indicators of heat stress and is related to a number of varied functions such as activity, nutrition, health preservation and reproductive success (Kumar *et al*. 2017). Sheep are able to maintain their internal temperature within a relatively narrow range (38.3–39.9°C) (Fielder 2019); however, some individuals are able to better maintain a relatively low body temperature under hot conditions. The objectives of the current study were (i) identify ewes with the ability to maintain a low core temperature when exposed to high ambient daytime temperatures, and (ii) validate the selection of ewes based on pre-determined temperature groups prior to summer joining.

Two groups of Merino ewes (*Ovis aries*) were selected from a flock of 293 (72.5 ± 8.1 kg body weight) at Turretfield Research Centre, Rosedale, South Australia (34°33′S, 138°50′E), according to their average daily vaginal temperature measured automatically at 10-min intervals. A silicon probe housing a temperature logger (Micro-T 16-bit; Star-Oddi, Iceland), was initially deployed once into each ewe during two, 3-day periods where maximum daily ambient temperature was ≥32.0°C. Low temperature status (LTS) and high temperature status (HTS) ewes had an average daytime vaginal temperature of ≤38.85°C and ≥38.95°C, respectively. The temperature loggers were then re-deployed at the same interval into selected ewes (n = 100 per group) in conjunction with a progesterone pessary for the synchronisation of oestrus over a 14-day period.

Vaginal temperature data during both measurement periods were normally distributed. Vaginal temperature was not correlated ($P > 0.05$) with ewe live weight (r = –0.125) but showed a weak negative correlation (P = 0.003) with ewe body condition score (r = - 0.213). Mean daytime vaginal temperature during oestrus synchronisation was lower ($P < 0.005$) for LTS (38.76°C ± 0.01) compared with HTS ewes (38.93°C ± 0.01) (Fig. 1). With reference to ewe selection, 72% of those representing the upper (n = 100) and lower (n = 100) extremes of the original flock were consistently grouped based on mean daytime vaginal temperature during oestrus synchronisation.

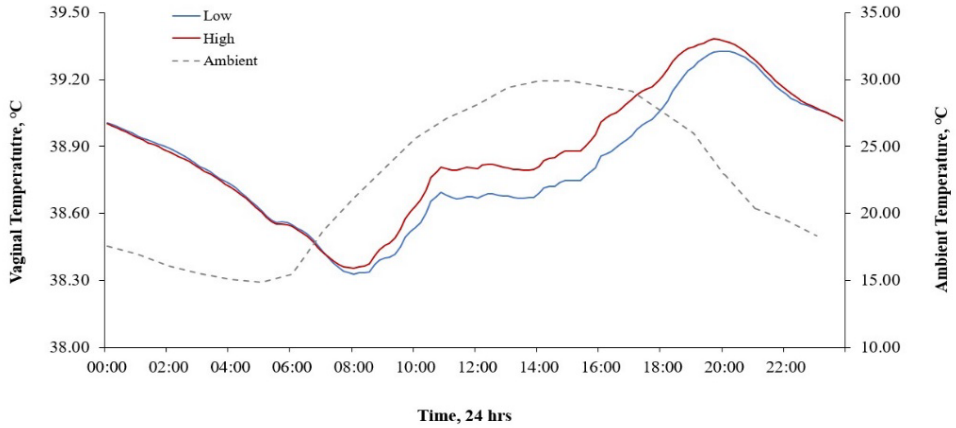

Fig. 1. Mean daily ambient temperature and vaginal temperature between groups measured across time during oestrus synchronisation. Pooled SEM: ±0.006 and ±0.009 °C for low (LTS) and high (HTS) temperature status groups, respectively.

Core temperature status of ewes prior to the time of mating can be used as a means of identifying subgroups of individuals in a commercial flock with varying thermoregulatory capabilities. Heat stress not only impairs reproductive processes, but high ewe temperature status has been linked to intrauterine growth restriction (IUGR) and low lamb live weights at birth. Therefore, selecting ewes with improved thermotolerance for the breeding flock could increase weaning rates by favouring optimal fetal growth and reducing reproductive failure. Future research should focus on linking observed ewe temperature status groups with reproductive outcomes as well as the growth and development of subsequent lambs, both in utero and post-partum.

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Virtual fencing does not cause more stress than physical electric fencing in grazing beef cattle

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Livestock husbandry has continually evolved to adopt new, advanced, and innovative technologies, such as virtual fencing. Virtual fencing could improve utilisation of seasonal forage growth, enable re-establishment of pasture biodiversity using exclusion areas (Anderson, 2007; Umstatter *et al.* 2015), while also allowing for 'virtual' herding or mustering of animals (Butler *et al*. 2006). It is paramount that the implementation of novel livestock management technologies does not hinder animal well-being. Therefore, the objective of these studies was to evaluate the effects of virtual fencing on stress biomarkers and behaviour responses in beef cattle when compared with 2-strand electric wire fencing in a rotational grazing management system.

All pastures utilised in these studies consisted of warm-season perennial grasses, primarily Bermuda grass (Cynodon dactylon) or yellow bluestem (Bothriochloa ischaemum). This research was conducted at the Bluestem Research Range at Oklahoma State University, 14.5 km SW of Stillwater, OK, USA. Cattle were contained by either physical, 2-strand electric fencing (PF) or by use of proprietary, GPS-based virtual fencing (VF) collars, with no physical interior fencing. Tail switch hair and fecal samples were collected on d 0 and 56 and were analyzed for cortisol concentrations to measure accumulated stress experienced by the cattle. A subset of cattle were fitted with pedometers to evaluate behavior. In Study 1, 55 Angus heifers (BW = 315 ± 30 kg) were rotationally grazed in 1 PF or 1 VF pasture over 28 d. In Study 2, 59 Angus, Beefmaster, and Angus-Herford cross mature cows and heifers (BW = 484 ± 84 kg) were rotationally grazed in PF or VF pastures (n = 2 pastures per fence type) over 56 d. Animals in Study 2 underwent at least 2 weeks of acclimation to the VF collars prior to the experiment. In the second experiment, blood samples were also collected to quantify non-esterified fatty acids (NEFA) and lactate in serum.

All data were analysed in R (R Core Team; 2020). Only descriptive statistics were summarised for Study 1. In Study 1, hair cortisol and fecal corticosterone concentrations (0.39 ± 0.3 and 0.37 ± 0.1 pg/mg cortisol, 140 ± 79.6 and 128 ± 56.7 ng/g corticosterone for PF or VF animals, respectively) in both fence types were within published normal ranges. Step counts and motion index appeared elevated in the first few days for VF, as animals adapted to VF. Study 2 was analysed using analysis of variance as a completely randomized design with pasture as the experimental unit. No effect of fence type was observed for standing time or lying bouts ($P > 0.16$). However, VF cattle moved more in the first few days than PF, but not later in the experiment ($P \leq 0.002$). Results of cortisol metabolites for Study 2 are presented in Table 1. No differences were observed in cortisol metabolites, lactate, or NEFA ($P \geq 0.14$) due to fence type.

Physiological metabolites measured in both studies were not found to be affected by fence type, and the expected correlations among these variables were absent or inconsistent across both studies. Therefore, we conclude that the application of a VF system to contain and rotate cattle proved to be no more stressful to the livestock than double-strand electrified wire fencing. However, further research is warranted to determine the extent of livestock management that may be achieved with the utilisation of VF.

Table 1. Effects of virtual fencing on cortisol metabolite concentrations of beef cattle: Study 2

	VF	PF	SE	*P*-value
Hair cortisol (pg/mg)				
d 0	0.52	0.29	0.072	0.16
d 56	0.09	0.17	0.046	0.34
Delta, d 56 – d 0	0.43	0.13	0.090	0.14
Fecal corticosterone (ng/g)				
d 0	168	224	43.7	0.46
d 56	223	265	37.5	0.51
Delta, d 56 – d 0	–56.8	–4.4	74.0	0.66

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The relationship between *in vivo* apparent nutrient digestibility, *in sacco* and *in vitro* Daisy™ dry matter potential degradability when increasing the inclusion level of canola meal in the ration

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Apparent nutrient digestibility is a measure of the total tract digestibility, whereas *in sacco* and *in vitro* Daisy™ (Ankom Daisy™ Incubator[II], Ankom Technology, New York, USA) methods are used to assess rate and potential degradability (PD) of feedstuffs. Few studies have directly compared *in sacco* and *in vitro* Daisy™ DM PD of a ration using fistulated animals which are fed the same ration (i.e. the incubated material is the same composition as the ration fed to the animals, Chaudhry *et al*. 2011; Krizsan *et al*. 2013). The objective of the current study was to determine the relationship between *in vitro* Daisy™ PD, *in sacco* PD and *in vivo* DM digestibility (DMD) when steers were fed rations containing varying inclusion levels of canola meal.

Three experiments: (1) *in vivo* apparent nutrient digestibility, (2) *in sacco* and (3) *in vitro* Daisy™ were conducted to measure apparent digestibility and PD of forage-based rations containing varying inclusion levels of canola meal. Experiment 1, 10 Angus steers (344 ± 6.42 kg, 12 months old) were in a partial crossover design which consisted of three experimental periods of 18 d (11 d dietary adaptation and a 7 d total collection period) during which steers were housed in individual metabolism pens and total collections recorded. Steers were offered a ration with one of five inclusion levels of canola meal (solvent extracted); 0%, 15%, 26%, 36% or 47% of dietary DM. Roughage was mixed barley hay and wheaten stubble providing ~8.35 MJ/kg DM, fed at 1.2 X maintenance (CSIRO 2007). Experiments 2 and 3 were conducted simultaneously using four ruminal fistulated Red Poll steers, (n = 2, 7 years old, 938 ± 7.86 kg; and n = 2, 5 years old 636 ± 8.76 kg) in a 4 × 4 Latin square design. Steers were offered barley hay and wheaten stubble with one of four inclusion levels of canola meal; 0%, 13%, 27% or 43% DM to provide the same M/D as Experiment 1. Each period had 11 d diet adaptation period, inserting *in sacco* bags and collection of ruminal fluid for *in vitro* Daisy™ incubation on Day 12. Samples of each diet were ground (1 mm) and weighed into dried, pre-weighed, Ankom™ F57 filter bags (25 micron). For *in sacco* degradation, 3 filter bags (containing 1.0 ± 0.2 g of sample) were placed inside Dacron bags and incubated for 72, 48, 24, 18, 12, 9, 6, 3 or 0 h. For the *in vitro* Daisy™ degradation, 2 filter bags (containing 0.5 ± 0.2 g of sample) were incubated in a mixture of 400 mL of ruminal liquor (collected from donor steers fed each ration) and 1600 mL of buffered artificial saliva (Adesogan 2005; Daisy™ 2021) with additional N (ammonium sulphate and urea) to ensure adequate N for fermentation (Kaiser *et al*. 2007) and incubated for the same times as the *in sacco* incubations. Following incubation, all bags were removed, washed and dried (80°C, 24 h). The DMD and PD were calculated as described by CSIRO (2007) and Ørskov (1979). The relationship between *in sacco* PD, *in vitro* Daisy™ PD and *in vivo* DMD was assessed using PROC REG procedure in SAS. An alpha of 0.05 was used for all statistical tests.

The *in vitro* Daisy™ PD of the canola meal dietary treatments was not significantly related to *in sacco* PD (R^2 = 0.59, P = 0.201; Fig. 1a). The *in sacco* PD (R^2 = 0.98, P = 0.012), but not *in vitro* Daisy™ PD (R^2 = 0.67, P = 0.183) of the canola meal dietary treatments were significantly positively related to *in vivo* DMD (Fig. 1b). These results indicate that *in sacco* PD is the recommended method when evaluating feedstuff.

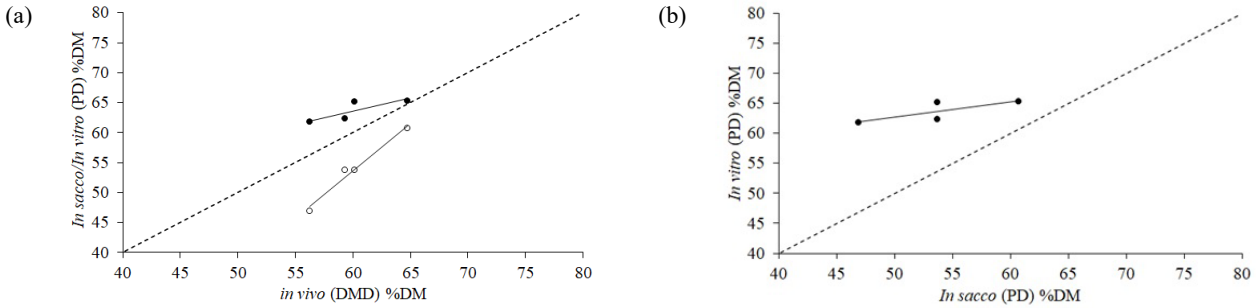

Fig. 1. (a) Correlation between *in vivo* dry matter digestibility (DMD) and *in sacco* (○) or *in vitro* Daisy™ (●) potential degradability (PD, after 72 h). (b) *In sacco PD* and *in vitro* Daisy™ PD (after 72 h) when the dietary treatment contained varying inclusion levels of canola meal (●) when steers were fed a ration containing varying inclusion levels of canola meal.

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Altering the source of ruminal inoculum on the dry matter degradation kinetics of rations containing varying inclusion levels of canola meal using *in vitro* Daisy

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The effect of varying the inclusion levels of canola meal within a low-quality roughage ration on degradation kinetic parameters is relatively unknown. The Ankom filter bag method using the Ankom Daisy^{II} Incubator^{TM} (Ankom™ Technology, USA) uses ruminal fluid from donor animals and artificial saliva to mimic the rumen environment and can determine degradation kinetic parameters (Tassone *et al*. 2020). With any assay measuring dry matter (DM) digestibility or degradation kinetics there are sources of variation including inoculum source (Mabjeesh *et al*. 2000). The diet an animal is fed can have a significant impact on the rumen environment which can affect the rate and extent of microbial fermentation. Therefore, the objective of this study was to determine whether DM degradation kinetics of rations containing varying inclusion levels of canola meal was altered when rumen liquor, used the *in vitro* Daisy ^{TM} assay was collected from steers fed varying inclusion levels of canola meal in either a low-quality roughage or a grain-based ration.

Four mature ruminal fistulated Red Poll steers were offered four rations based on barley hay and wheaten stubble containing 0%, 13%, 27% or 43% of canola meal (DM basis) in a 4 × 4 Latin square design with an M/D of approximately 8.32, 9.85, 10.29 and 10.78 MJ/kg DM and 91.3, 147.9, 176.8 and 228.6 g/kg crude protein (CP), respectively. In an additional feeding period, the steers were also offered a grain-based ration containing 15% oats, 15% barley grain, 35% barley hay and 35% lucerne hay, with an M/D of approximately 9.39 MJ/kg DM and 122.8 g/kg DM of CP. The rations were offered twice daily, at 1.2 times maintenance (CSIRO 2007). Each period consisted of an 11 day adaptation, with ruminal fluid for *in vitro* Daisy incubation collected on Day 12, with the dietary treatments (samples) incubated in the *in vitro* Daisy ^{TM} machines the same composition as the canola meal rations fed to the steers. Sample components were ground to 1 mm and weighed into dried, pre-weighed, Ankom™ F57 filter bags (25 micron porosity) based on treatment and sealed. Two filter bags per jar, each containing 0.5 ± 0.2 g of sample were incubated in one of two Daisy ^{TM} machines for 72, 48, 24, 18, 12, 9, 6, 3 and removed at 0 h. Each jar contained a mixture of 400 mL of ruminal liquor (collected from the donor steers fed each ration) and 1600 mL of a buffered artificial saliva (Adesogan, 2005; Daisy Technical Manual, 2021) with additional N (ammonium sulphate and urea) added to ensure adequate N for fermentation (Kaiser *et al*. 2007). At the end of 72 h incubation period, the bags were removed, washed and dried at 80°C for 24 h. Differences in digestibility losses (CSIRO 2007) and degradation kinetics parameters (Ørskov 1979) for each treatment were determined using the mixed model procedure using SAS.

Table 1. ***In vitro*** **Daisy^{TM} ruminal digestion kinetics, potential degradation (PD) and effective degradability (ED, considering outflow rates of 0.02 and 0.05/h) of the canola meal dietary treatments containing either 0%, 13%, 27% or 43% DM when the ruminal liquor was collected from steers fed a grain-based ration (STD)**

Degradation coefficients (%)	Dietary treatment 0			Dietary treatment 13			Dietary treatment 27			Dietary treatment 43		
	Ration 0	Ration STD	sem	Ration 13	Ration STD	sem	Ration 27	Ration STD	sem	Ration 43	Ration STD	sem
b	39.04^{a}	48.67^{b}	4.09	41.43^{a}	46.93^{b}	1.78	45.06^{a}	54.70^{b}	3.81	39.16^{a}	55.15^{b}	2.71
c	0.029	0.037	0.004	0.016^{a}	0.042^{b}	0.006	0.037	0.046	0.011	0.010^{a}	0.046^{b}	0.009
PD	57.23^{a}	67.06^{b}	4.09	64.21^{a}	69.70^{b}	1.78	65.19^{a}	74.83^{b}	3.81	60.34^{a}	76.33^{b}	2.71
$ED_{0.02/h}$	42.26	50.21	3.46	39.55^{a}	51.81^{b}	3.70	48.42	58.17	6.09	36.72^{a}	57.97^{b}	3.27
$ED_{0.05/h}$	33.09	39.20	2.75	31.95^{a}	42.04^{b}	2.38	38.86	46.26	4.98	28.65^{a}	46.66^{b}	2.73

Different superscripts within rows for each parameter indicate a significant difference ($P < 0.05$) between dietary treatments. b = slowly degradable fraction (not soluble); c = fractional rate of degradation of b(/h) from the fitted exponential equation PD = a + b (1- e^{-ct}).

The DM PD and the b fraction was significantly higher ($P < 0.05$) when the ruminal liquor was collected from steers fed the standard ration compared with the canola meal rations. The ED at outflow rates of 0.02 and 0.05/h and the c fraction was higher for the 13 and 43% dietary treatments compared with the 0 and 27% dietary treatments when the ruminal liquor was collected from steers fed the standard ration compared with the canola meal rations. While it is possible observed differences could have occurred due to period variation, the results indicate degradation kinetics are higher when ruminal fluid is collected from steers fed a grain-based ration compared with a forage-based ration.

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Phenotypic correlation and repeatability for consumer derived tenderness between beef muscles

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The beef industry has identified consumer satisfaction as a key factor in how much consumers are willing to pay for their meat as well as how likely they are to repurchase. Current consumer satisfaction prediction involves utilising objective carcass measurements such as marbling, meat colour and ossification to determine a grade. The US and Japanese grading systems determine a single grade for the entire carcass based on loin measurements. Due to large variation in eating quality between cuts, a single grade applied for a whole carcass may be inadequate (Bonny *et al*. 2018). However, the repeatability of tenderness within animal and the correlation between multiple cuts has not been studied in detail. The aim of this study was to examine the repeatability for tenderness across cuts within an animal and the phenotypic correlations between multiple cuts to determine if measurements taken from one location is sufficient to apply a single carcass grade. This study utilised the phenotypic and sensory information collected for five cuts; EYE075 (*m. semitendinosus*), OYS036 (*m. infraspinatus*), OUT005 (*m. biceps femoris*), TDR062 (*m. psoas major*), STR045 (*m. longissimus lumborum*) from 503 different animals across 29 kill groups. Each of the five cuts were sensory tested by 10 untrained consumers using a grill cook method and rated on a 0-100 scale for tenderness, juiciness, flavour and overall liking. The top and bottom two scores were clipped and the remaining six values averaged for each trait. The restricted maximum likelihood (Reml) method was used with a linear mixed effects model to estimate variance components for repeatability. Cohort, Cut and ageing post-mortem were used as fixed effects with animal set as a random effect. Each observation was added one at a time to observe the effect of increased cuts on repeatability within animal. Phenotypic correlations between cuts and variance components were estimated using ASReml to remove variance explained by the fixed effects above. A very low repeatability estimate of 0.086 was observed within an animals five cuts. Correlations (as shown in Table 1) were low to moderate: ranging from –0.04 to 0.20. Only five of the correlations observed between muscles were significantly different from zero. There was significantly less variation observed for OYS036 and TDR062 when compared to the other three cuts.

Table 1. Tenderness variance (diagonal) and correlations (upper triangular) between cuts

	EYE075	OYS036	OUT005	TDR062	STR045
EYE075	194.7 (12.6)	0.11 (0.05)*	0.20 (0.04)*	0.12 (0.05)*	0.08 (0.05)
OYS036		90.9 (5.9)	0.09 (0.05)	0.19 (0.04)*	–0.01 (0.05)
OUT005			198.3 (12.9)	0.06 (0.05)	0.18 (0.04)*
TDR062				54.4 (3.5)	–0.04 (0.05)
STR045					195.1 (12.7)

*Correlations significantly different from zero at $P < 0.05$.

The current study demonstrated the low repeatability for tenderness within animals over multiple cuts with only minor correlations between those cuts studied. Shackelford *et al.* (1997) observed the repeatability within two cuts and found that the sample location of the EYE075 accounted for more variation than between animal variation. The same study reported a similar correlation (0.12) to ours between the EYE075 and the *longissimus thoracis et lumborum,* suggesting that a single measurement from the loin is inadequate to describe the whole carcass. The variation between cuts for tenderness is well documented however this study is one of very few to observe repeatability and correlations between multiple beef cuts. Variation between cuts is to be expected due to the difference of connective tissue observed between muscles, hindering the aging potential of some muscles when compared to others (Thompson 2002). Guy *et al.* (2022) measured the genetic correlation for tenderness between the loin and topside cuts of lamb and reported moderate to high correlations, suggesting the potential for genetic prediction of tenderness between cuts. It is understood that many muscle characteristics, such as connective tissue and calpastatin activity, are impacted by genetic factors. Bos *indicus* content is well documented to be correlated with higher levels of calpastatin activity post-mortem, inhibiting proteolysis (aging) by calpain enzymes (Aroeira *et al*. 2016).

The low correlations and repeatability observed in the current study suggest that applying a single grade for a carcass via measurements taken at the loin without factoring in muscle variation is inadequate. Examining the genetic correlation between muscles may provide more accurate prediction for consumer satisfaction.

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Comparing eutocia and dystocia: a case study using Smart Paddock GNSS collars

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Dystocia is a major contributor to calf death at or shortly after birth and can directly impact calf survivability up to 30 days postpartum (Lombard *et al.* 2007). Current methods for identifying dystocia are subjective, laborious, and are mostly unsuitable for extensively grazed beef systems. Remote, on-animal sensing technologies have the potential to overcome some of these challenges. As part of a broader study investigating dystocia detection, this case study aimed to compare eutocia, dystocia, and general non-calving behaviour data collected using a commercial Smart Paddock Global Navigation Satellite System (GNSS) collar.

Pregnant, yearling mated, Braford heifers (n = 40), extensively grazed at a property located 40 km north of Clermont, were fitted with Smart Paddock GNSS collars (Smart Paddock, Vic., Australia), programmed to capture geolocation at 10-min intervals. Mean speed, aggregated for each hour, was calculated using the R environment within RStudio version 4.1.1 (R Core Team 2021). Derived features were compared and assessed for changes during the period surrounding parturition.

The data from the period of general non-calving behaviour indicated a decrease in movement from late morning until early evening coinciding with their grazing patterns. Parturition (both eutocia and dystocia) was found to disrupt this pattern, with a decrease in movement prior to and during parturition events (Fig. 1). Expulsion of the calf was successfully completed within two hours after presentation of the amniotic sac in the eutocic calving. For the cow that underwent dystocia, no progress was observed following two hours and assistance was provided. An increase in mean speed was observed within three hours following calf expulsion for the eutocic cow (Fig. 1). Conversely, no increase in movement was observed in the animal that experienced dystocia and this animal was euthanised four hours later (Fig. 1).

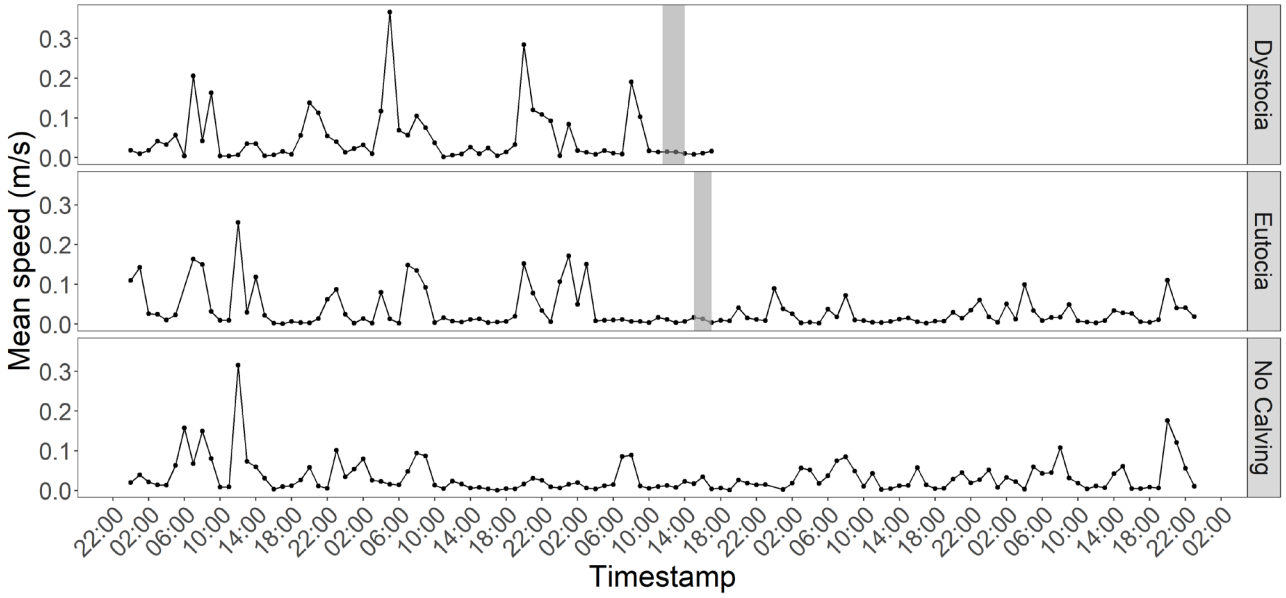

Fig. 1. Mean speed per hour (m/s) captured using GNSS collars for a dystocia, eutocia and non-calving event. Shaded areas represent stage 2 of parturition, beginning with the observation of the amniotic sac at the vulva and concluding with the expulsion of the calf. Expulsion of the calf for the animal with dystocia required manual assistance and this animal was later euthanised.

This study demonstrated the potential in using GNSS technology to detect parturition events, specifically dystocia, in extensive beef systems. Based on this case study, parturition events and type (eutocia or dystocia) can be identified through deviations from grazing patterns and reductions in activity, as captured using Smart Paddock GNSS collars. Studies using larger sample sizes are required to validate these findings and determine the repeatability of these results.

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The extreme distances sheep will go: distance travelled of rangeland sheep in Australia

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The monitoring of livestock previously relied on direct human behavioural observations, which provided the fundamental understanding of the diurnal behaviour of sheep. Over the past decade, on-animal sensors that provide location, activity and/or behaviour information have grown immensely due to their ability to increase the level of livestock monitoring. This is particularly valuable for the monitoring and management of rangeland sheep, due to their extensive and low input nature. Furthermore, on-animal sensors have improved our ability to investigate the variety of underlying factors affecting sheep behaviour and utilisation of their environment, such as shelter (Taylor *et al*. 2011), climate and heat stress (Thomas *et al*. 2008) and during lambing (Fogarty *et al*. 2020). Whilst travelling or walking by sheep is a fundamental behaviour, there is limited published information on the distance sheep travel and the subsequent health and welfare implications. The aim of this study was to investigate the distance travelled of rangeland sheep as a potential measure of health and welfare status.

On-animal sensors in the form of a collar that contained an i-gotU GT-600 GPS logger (Mobile Action Technology Inc., Taipei, Taiwan) configured to collect a positional fix every 5 mins were deployed on 'Dunraven', a 25 900 ha sheep grazing property in western Queensland, Australia. This 16-month study included five 30 day recording periods with either wethers: Grp1 (August 2019) or ewes: Grp2 (August 2019), Grp3 (November 2019), Grp4 (February 2020), Grp5 (August 2020), where Grp indicates the Group number. Drought conditions were apparent during the study. Daily distance travelled was calculated and differences between recording periods reported. Statistical significance was determined as $P \leq 0.05$. Results indicated a significant variation in distance travelled between individual sheep, with the daily distance travelled ranging from 1.87 km/day to 16.94 km/day (Fig. 1). There were also significant differences in the daily distance travelled between recording periods.

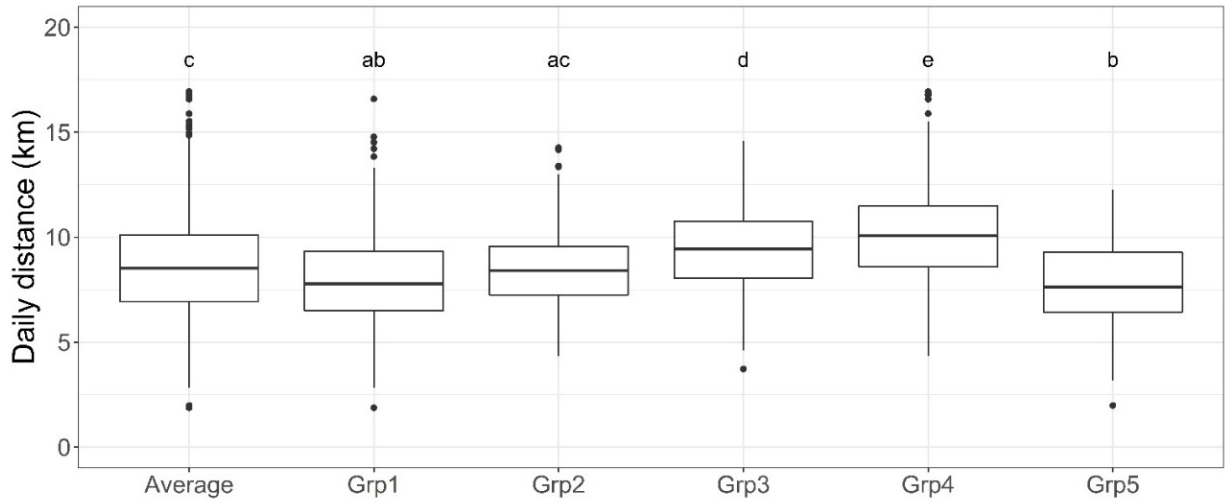

Fig. 1. Distance travelled (km) across five recording periods (Grp1 to Grp5) and for the study period (average). Pairwise comparisons are shown where common notation refers to no significant difference.

Extreme distances travelled as seen in the present study (16.94 km/day), especially during drought conditions has serious productivity, health, and welfare implications, or can be indicative of aberrant activity such as the presence of wild dogs (Evans *et al*. 2022). On-animal sensors are emerging as a realistic and valuable tool for rangeland sheep and will bring significant benefits for sheep producers and woolgrowers through improved management decision and intervention measures. In turn, this can have implications for the future of animal welfare, monitoring and legislative compliance (Manning *et al*. 2021).

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Usuckled Project: ability to detect calving events and observed gestation lengths

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The use of remote technologies to detect key production events, such as calving, in support of investigating problems such as calf wastage, has recently received considerable attention and investment. The Taggle™ calf alert system was developed to identify the time and location of calving events. The system has multiple components: active transmitters which are inserted intravaginally into pregnant cattle, and multiple in-field Taggle receivers with overlapping coverage (Stephens *et al*. 2019). At the time of transmitter expulsion, during a parturition event, detection of improved reception (i.e. detection by multiple receivers of increased signal frequency and strength) by receivers indicates a calving event, while the time difference for arrival of signals at receivers can be used to predict location. A modified Calf Alert system (single receiver only) was deployed to alert researchers of calving events to enable assessment of cow and calf behaviour around the time of calving in the Meat and Livestock Australia funded 'uSuckled' project. This paper describes the ability to detecting calving events using a modified Calf Alert system.

The study was conducted at the Katherine Research Station (Katherine, Northern Territory) between October 2021 and February 2022. At approximately one month from expected calving (assuming a mean gestation length of 290 days) 24 Brahman heifers confirmed pregnant from fixed-time artificial insemination were mustered to cattle yards to enable insertion of the Calf Alert transmitters. On presentation at the veterinary crush, each heifer was restrained without head bailing with the kick-gate closed behind them, the vulva was then cleaned and the Calf Alert transmitter loaded into a disinfected applicator. The transmitter was placed adjacent to the cervix. Afterwards, the heifer was rectally palpated to check the transmitter was correctly placed. The KoolCollect crush-side individual animal data recording software was used to record the unique ID of each transmitter. An in-field Taggle™ receiver was erected within 1.5 km of the study paddock, consisting of a transportable platform housing a 110 Ah per day solar system with 660 Ah battery storage and an 8m mast, which the Taggle aerial was attached to. TerraCipher Pty Ltd were engaged to access and analyse data in real time with calving alerts sent via text and email. From 2 weeks prior to the expected date of calving, the heifers were visually observed twice per day to identify calving events.

Substantial challenges were incurred with remotely detecting calving events in this study. Six heifers calved while the system was not operating correctly due to delays in establishing connections to real-time data flows. However, when data flows were established, no calving events were accurately predicted by the system due to existing algorithms being based on transmissions being detected by multiple receivers. However, detection of change points in rate of pings and receiver signal strength index successfully identified the day of calving for 17 of 18 calving events.

An average gestation length (GL) of 289.6 ± 1.2 days was observed (range 279–301 days). Hence, a 21-day spread of calving was observed for conceptions occurring during a single day. Sire (semen from 5 bulls used) did not significantly contribute to the observed variance in GL ($P = 0.92$). A 2.5-day greater GL was observed for male calves, when compared to females (Male = 291.6 ± 3.0 vs Female = 289.2 ± 2.6 days; $P = 0.60$). These findings are consistent with published reports by Corbet *et al.* (1997) and Plasse *et al.* (1968).

This study illustrates the potential challenges from using commercially available technologies to detect calving events, but also highlights the potential usefulness of this technology given the inherent marked variation in GL observed in Brahman cattle.

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Prediction of *in vivo* digestibility using a broad range of *in vivo* standards produced from Australian pastures and forages

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Digestibility is a key nutritional measure used to evaluate the quality of feeds and is used to estimate the metabolisable energy (ME) available for sheep and cattle (CSIRO 2007). Feed laboratories regularly use NIR calibrations to predict digestibility at maintenance feeding level, based on *in vitro* digestibility using either rumen fluid (Tilley *et al.* 1963), or pepsin cellulase (Clark *et al.* 1982) methods, with digestible organic matter in the dry matter (DOMD) used to estimate ME of the feed (CSIRO 2007). While NIR calibrations developed on *in vitro* techniques generally achieve good correlation coefficients (typically between 0.70–0.95; Kitessa *et al.* 1999), these *in vitro* techniques are only a prediction of *in vivo* digestibility. Error can also be compounded by the use of *in vivo* standards in the *in vitro* assays that do not match the samples analysed (Coates 2010).

NIR calibrations based on primary *in vivo* standards potentially bypasses the error associated with *in vitro* predictions (Kitessa *et al.* 1999). The objective of the current study was to determine whether an NIR calibration could be created directly for *in vivo* DOMD that covered a range of species at maintenance and *ad lib* feeding levels, A total of 358 *in vivo* standards were from three separate sources (NSW DPI Wagga Wagga Agricultural Institute, CSIRO Floreat WA, and HAEN P/L) representing various studies including tropical grasses and legumes, temperate and tropical silages, native species and some grains were included. Digestibility estimates were from either sheep and/or cattle and at *ad lib* and/or maintenance feeding levels.

Samples were ground with a 1 mm sieve, dried for 2 h at 80°C and scanned on a BRUKER™ Multi-Purpose NIR Analyser. The average of 32 scans per sample were subject to mean centring and a 17-point smoothing function and frequency region of 3700 to 8500 nm. Partial Least Squares (PLS) calibrations were created using OPUS software (Bruker Optik™, version 7.5). Sample scans were randomly allocated by the OPUS software into two subsets; a larger calibration set and a smaller independent validation set to assess the model.

NIR calibrations were developed for DOMD at maintenance (DOMD-Mn) or *ad lib* (DOMD-Ad) feeding levels.

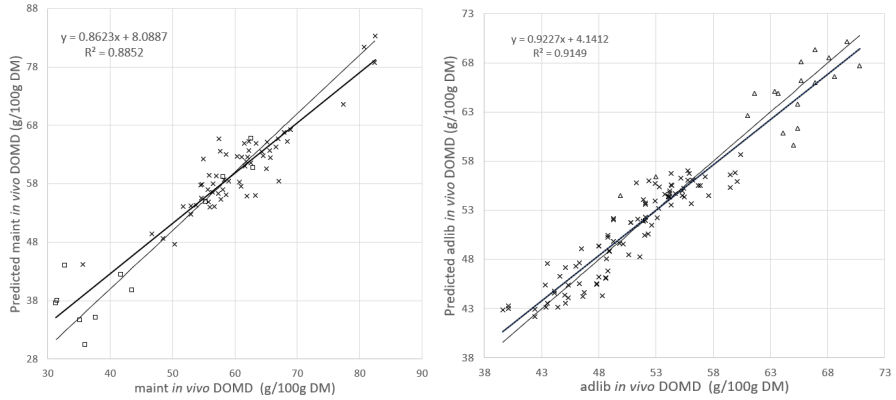

Fig. 1. NIR cross validation graphs for prediction of DOMD at maintenance and DOMD at *ad lib* feeding levels**.** x = WWAI, □ = CSIRO Floreat, and ∆= samples by D. J. Minson and provided by CSIRO and Haen P/L.

The DOMD-Mn calibration used 92 standards and 14 test spectra, with a range of 53.9–80.4% and used a 2nd derivative data pre-treatment. DOMD-Ad used 113 standards and 27 test spectra with a range of 44.0–71.7% and used a 1st derivative data pre-treatment. The Standard Error of Prediction (SEP) for both DOMD-Mn (2.42%) and DOMD-Ad (2.75%) were comparable to SEP values obtained for invitro methods, and other calibration statistics such as R^2 were also satisfactory. These calibrations were then tested on a range of forages collected over a year at the NSW DPI Feed Quality Service Laboratory to check the incidence of spectral outliers. These included samples of legume, pasture and cereal hay and silages. Of the 5622 samples scanned, the spectral outlier rate was low (DOMD-Mn = 0.1%, DOMD-Ad 2.4%), indicating the calibrations could be used on a wide range of samples, and have the potential for commercial or research use.

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Influence of time since last meal on methane emissions of sheep offered ad libitum diets using automated feeders

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Using Portable Accumulation Chambers (PACs) to screen sheep for methane emissions is more cost effective and less complex than respiration chambers and allows for larger numbers of animals to be tested, which has benefits for ranking animals for genetic selection (Muir *et al*. 2021). However, feeding patterns may influence the timing of peaks and troughs in methane emissions. As a result, researchers have developed measurement protocols that attempt to reduce individual variation in feed consumed and timing of meals prior to testing (Robinson *et al*. 2015). This involves holding animals off feed for an extended period, before allowing access to feed for a limited time. Considerable variation in the feed consumed during the access period has been reported, resulting in increased variability in measured emissions (Robinson *et al*. 2015). Automated feeding systems allow the collection of detailed individual feeding behaviour data such as the timing and size of meals. Methane emissions measured from sheep offered diets ranging from 40% to 180% of maintenance requirements were affected by both level of feeding and the time since last meal, with these variables contributing 58.7% of variation in an additive linear model (Muir *et al*. 2021). This observational study aimed to examine the relationship between time since last meal and methane emissions for sheep fed *ad libitum* from automated feeders while being tested for feed efficiency.

The data used for this analysis was collected from five feed efficiency experiments (Muir *et al*. 2020*a*) undertaken using the automated feed intake facility at Department Jobs, Precincts and Regions (DJPR) Hamilton, Victoria, Australia between 2014 and 2016. Experiments were approved by the DJPR Agricultural Research & Extension Animal Ethics Committee (AEC Proposal 2013-23, 2105-09 and 2016-05). The automated feeding system has previously been described by Muir *et al*. (2020*b*) and was used to offer pellets (9.6 MJ/kg DM and 9.8% CP) *ad libitum* to 505 ewes at three different ages. Feed intake was measured for a minimum of 35 days in each experiment. Methane was measured using PACs on two occasions near the end of each experiment using the approach of Goopy *et al*. (2011). This resulted in up to 6 methane measurements for an individual ewe. Feed intake and time of meals was recorded by the automated feeding system. REML (restricted maximum likelihood) analysis was undertaken using GenStat (version 18.2) on 1770 measurements of methane production (CH_4 g/day) examining the influence of dry matter intake (DMI) in the 24 h prior to testing and the log transformed time since last meal (TIME) as fixed effects. The experiment (comprising flock and age), pen, date of methane measurement and individual ewe were included as random effects. Interactions and a quadratic term for DMI were examined but excluded from the models as they did not markedly improve the variance explained (less than 0.5%).

Table 1. Models for the relationship between methane emissions (g/day) and dry matter intake (DMI) in the last 24 h and the time since last meal (TIME)[A]

Model terms	DMI	TIME	DMI + TIME
Constant	25.64 ± 3.283	52.51 ± 4.279	42.10 ± 3.644
DM 24 h intake (kg DM)	5.06 ± 0.343		3.97 ± 0.336
Time since last meal (min)		–3.67 ± 0.225	–3.04 ± 0.223
Variance explained (%)	57.7	58.8	61.7

[A]Coeffcients (± s.e.) for each term are presented. Time since last meal was log transformed for analysis. All terms were significant $P < 0.001$.

Average DMI (1.98 ± 0.019 kg) in the 24 h prior to testing and subsequent methane emissions (36.4 ± 0.316 g/day) were higher than in Muir *et al*. (2021) but the average TIME of 4.73 ± 0.024 (back transformed 113.1 min) was similar to the average recorded at the highest level of feeding in that experiment. Both DMI and TIME explained a significant proportion of the variation in methane emissions when considered alone, but the model was improved with the use of both terms (Table 1). The improvement in variance explained and the size of effects for both terms are less than observed in Muir *et al*. (2021), most likely due to *ad libitum* feeding resulting in a lower effect of the time since last meal on rumen turnover and hence methane emissions. When sheep are fed *ad libitum* the time of last meal is less likely to contribute to the re-ranking of sheep, however corrections using this data or protocols to reduce the effect on methane measurements should be considered.

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Wool provides key insights into the physiological sensitivity of Merino sheep to environment and management intervention

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Merino sheep provide significant contributions to Australia's economy and food supply. Wool production can be impacted by climate and it is important to monitor individual performance using newly available tools. Our research has focussed on validating a practical method of wool sampling for the evaluation of hormone profiles for research purposes, and to understand how hormonal variation may be related to wool phenotype and sheep productivity. We have investigated variation in wool cortisol (a physiological stress biomarker) and wool micron (MIC) in Merino ewes (*Ovis aries*) and weaners from western Queensland, New South Wales and Tasmania. The key finding of this study is that wool glucocorticoid levels show strong between-animal variation that is also influenced by seasonal variation and the life-history stage of livestock (e.g. breeding versus non-breeding period) (Table 1). Further, statistical analysis showed strong correlation between wool cortisol levels and change in MIC.

Table 1. Wool hormone studies conducted by the Stress Lab, the UQ

Study	Question asked	Animals	Location	*P*-value	Conclusion
Pre-and post-partum variation in wool cortisol and wool micron in Australian Merino ewe sheep (Ovis aries)	Does fiber diameter differ between pre- and post-lambing? Does wool cortisol pre-lambing have a negative correlation with wool micron?	38 ewes	Braidwood, NSW, Australia	$P < 0.05$, $P < 0.001$	84.6% of ewes expressed finer wool at lactation. Wool cortisol levels pre-lambing showed significant negative correlation with wool micron
Interplay between stress and reproduction: Novel epigenetic markers in response to shearing patterns in Australian Merino sheep (Ovis aries)	How does shearing frequency influence the grazing activity, body condition, epigenetics and cortisol of pregnant ewes?	48 ewes	Cattai, NSW, Australia	$P < 0.05$	Twice shorn ewes had higher grazing activity, better body condition, and lower stress levels. Lambs born to twice shorn ewes had finer wool with better comfort scores
Chronic elevation of plasma cortisol causes differential expression of predominating glucocorticoid in plasma, saliva, fecal, and wool matrices in sheep	What is the relationship between of blood plasma cortisol and cortisone and that of cortisol and cortisone found in saliva, feces, and wool?	12 ewes	Rosedale, SA, Australia	$P < 0.05$	Wool fibre has significant advantages as a matrix for quantifying chronic HPA activation

Wool can therefore provide a convenient biological sample for assessing physiological stress in Merino sheep and the within and between individual animal variation in hormonal levels that are closely related to on-farm climate and management intervention. Our future research aims how environmental change may impose sub-clinical stress in livestock and to determine the threshold of stress response that moves between acute response and chronic stress. This will provide the basis for a reliable tool to enable farmers to reliable tool for assessing the stress status of their animals so they can make management changes to reduce stress and improve performance and productivity. Wool provides a useful biological sample for assessing the hormonal physiology of Merino sheep, especially for tracking glucocorticoid levels and can have a key application in making assessments of sheep welfare and responses to environmental and management changes.

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Remote automated weighing and physiological status of extensively raised breeding cows

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Large scale commercial cattle breeding operations in northern Australia have limited opportunity to collect individual animal and herd data due to the spatial and temporal scale in which they operate. Remote monitoring of live weight changes in breeding cows in extensive grazing conditions could be used to predict and manage reproductive performance, mortality, and profitability.

A total of 220 cows were included in the trial herd over a 2-year period, with walk over weighing (WoW) stations set up at water points in the paddock which monitored live weight throughout the trial. The present study used crush side data at each muster along with remotely collected WoW data to monitor the effect of lactation and pregnancy status on live weight changes of breeding cows over two years. Crush side data was collected at each muster at the end of the wet season (April) and dry season (October and November), including weight, lactation status and pregnancy status. The objective of the study was to remotely collect live weight (LW) and live weight change (LWC) data of individual cows in commercial breeding operations, and to determine the differences in LWC according to pregnancy and lactation status of breeding cows.

Table 1. Crush side data collected from cows according to reproductive status at the end of the dry season in 2019

Variable	Not pregnant				Pregnant		*P*-value
			Lactating		Lactating		
	Not lactating	Lactating	Not weaned	Weaned	Not lactating	Weaned	
N	20	19	47	58	36	2	
Start of dry season 2019							
Weight (kg/head)	390 ± 15.4^{b}	423 ± 16.6^{ab}	387 ± 9.9^{b}	453 ± 7.5^{a}	397 ±11.1^{b}	492 ± 33.3^{ab}	<0.001
Days to calving[A]	289 ± 8.9^{ab}	290 ± 8.5^{ab}	288 ± 5.4^{a}	259 ± 4.0^{b}	301 ± 8.5^{a}	251 ± 17.8^{ab}	<0.001
End of dry season 2019							
Weight (kg/head)	338 ± 11.1^{ab}	307 ± 11.4^{b}	293 ± 7.3^{b}	315 ± 5.8^{b}	379 ± 8.3^{a}	366 ± 28.8^{ab}	<0.001
LWC dry season (kg/head)	–52.07 ± 9.84^{b}	–101.00±10.63^{bc}	–87.76 ± 6.31^{b}	–132.95± 4.79^{c}	3.56 ± 7.08^{a}	–125.67±21.25^{bc}	<0.001
End of wet season 2020							
Weight (kg/head)	449 ± 12.7^{a}	407 ± 13.8^{ab}	354 ± 8.5^{b}	442 ± 6.7^{a}	425 ± 9.6^{a}	502 ± 32.0^{a}	<0.001
LWC wet season (kg/head)	113.06 ± 8.56^{a}	96.94 ± 9.32^{ab}	61.52 ± 5.75^{bc}	126.04 ± 4.52^{a}	43.98 ± 6.49^{c}	135.84 ± 21.54^{ab}	<0.001

[A]Days to calving from pregnancy testing in April 2018 at the start of the dry season.
LWC, live weight change.

Mixed effects models were run with LW or LWC as the dependent variable, and date and lactating and pregnancy status as fixed effects. There was a significant interaction between day and lactation, and pregnancy status on LW and LWC of cows across both years ($P < 0.001$). Cows that were lactating at the end of the dry season lost 108 ± 47 kg/hd of LW, whereas those that were not lactating lost 36 ± 50 kg ($P < 0.05$; Table 1). Cows that had their calves weaned at the end of the dry season gained 131 ± 2.8 kg and 126 ± 5.1 kg throughout the 2019 and 2020 wet seasons, respectively, compared to cows that did not have their calf weaned prior to the wet season, which only gained 50 ± 4.36 kg and 61 ± 4.52 kg, respectively ($P < 0.001$; Table 1).

This study shows the value of collecting crush side data over time to determine productivity and reproductive status of cows in large scale commercial systems. Cows that lactated during the dry season had LW losses of up to 1.7 kg/day which indicated that calving in the dry season and not weaning at the end of it may compound the effect of LW loss to put cows at greater risk of poor animal welfare (Galina 2019). This information could be used for nutritional and reproductive management of cows in extensive conditions. Further investigation could help to identify animals better able to maintain weight during the dry season and lactation, helping to improve reproductive performance in extensive systems.

Reference

Galina CS (2019) *Animals* **9**, 223.

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The accuracy of the Optium Neo™ handheld glucose-ketone meter for testing ewe blood samples

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Suboptimal levels of blood glucose and beta-hydroxybutyrate (BHB) are risk factors for ketosis, a disease more common to multiple-bearing ewes in late pregnancy. Handheld devices that test blood glucose and ketone levels have been designed to be mobile, quick, and inexpensive alternatives to laboratory-based blood tests (Rodriguez, *et al.* 2021). These devices were developed for human blood but have potential application to livestock to easily screen and monitor individual animals. The capacity to monitor the blood of pregnant ewes with instantaneous results would be advantageous, as early diagnosis of ketosis is critical to recovery from the disease. To inform industry as to the accuracy of these devices, this study used blood samples from pregnant ewes with the objective to compare the glucose and BHB results with those from laboratory-based methods and from an Optium Neo™ Blood Glucose and Ketone Meter (Freestyle).

The study was approved by the NSW DPI Orange Animal Ethics Committee (ORA 19/22/026). Twin-bearing Merino ewes (n = 47) were identified as 'early joined' by ram harness raddle marks and ultrasound diagnosis. Blood samples were collected once weekly for 4 weeks in late pregnancy. Lambing commenced 8 days after the date of last blood collection and finished 15 days later. Blood samples were collected via jugular venipuncture (K^+ EDTA, 9 mL), from which blood was taken using the FreeStyle Glucose test strip and the FreeStyle Ketone test strip. These were immediately inserted into an Optium Neo™. The remaining blood samples were placed on ice and within 2 h were centrifuged for 15 min at 3500 rpm. The plasma was decanted and held at –18 °C until laboratory testing. The laboratory-based blood tests for glucose and BHB followed the colorimetric protocols prescribed by the Glucose Assay Kit (MAK263, Sigma-Aldrich) and the BHB Assay Kit (MAK041, Sigma-Aldrich). Data were analysed in Stata (version 14.2) using Bland-Altman plots to test for the limits of agreement between the two tests for glucose and BHB.

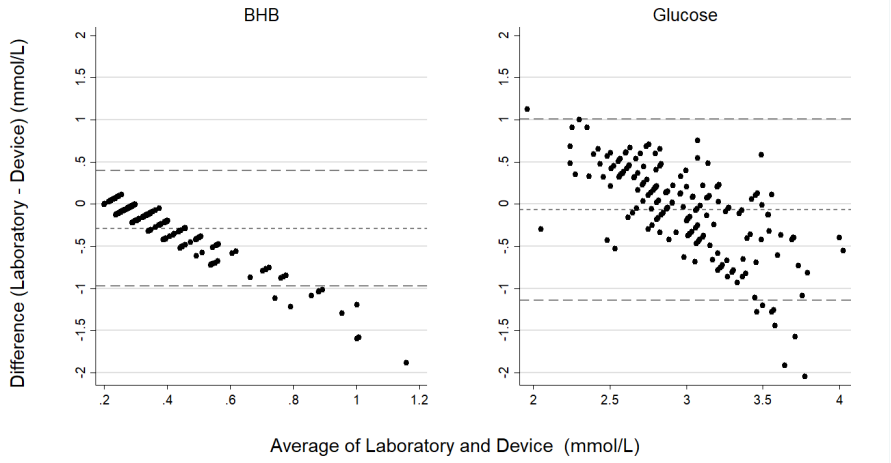

Fig. 1. Bland-Altman plots for laboratory-based (Laboratory) and Optium Neo™ handheld monitor (Device) blood test results for the content of beta-hydroxybutyrate (BHB) and glucose in blood from pregnant ewes. The dotted line represents the mean (bias) and the dashed lines represent 1 SD of the bias.

The majority of data were within the limits of agreement ($\bar{X} \pm 1$ SD), which suggests some comparability between the laboratory-based and Optium Neo™ blood test results (Fig. 1). There was, however, a linear trend observed between the two methods, whereby the difference between blood test results increased as the BHB and glucose content increased. In both tests, the Optium Neo™ overestimated the result when compared to the laboratory test. The mean difference and its standard deviation for BHB were –0.29 ± 0.34 and for glucose were –0.07 ± 0.54, indicating large coefficients of variation. This finding suggests caution when using the Optium Neo™ as an alternative to laboratory-based blood tests on occasions when ewes may have high levels of BHB or glucose in their blood. Analysis of the sensitivity and specificity, account of dietary treatment, as well as a larger sample base could help provide greater resolution to this comparison.

Reference

Rodriguez Z *et al.* (2021) *Veterinary and Animal Science* **11**, 100159.

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Automatic monitoring of body weight of Poll Dorset ewes in late gestation and lactation

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The use remote monitoring systems can be used to achieve a better understanding of animal behaviour and performance without human interaction with less stress. Automatic weighing of sheep in the paddock could provide real-time information on the nutritional, gestational and lactational status of ewes. The objective of this research is to use remotely monitored walk over weighing platforms in Poll Dorset ewes during late gestation and lactation in a commercial application.

This study was approved by the Sydney University Animal ethics committee and used 608 mixed-age pregnant Poll Dorset ewes. The trial was conducted over 289 days (12 December 2020 to 26 September 2021). A walk over weighing platform with cellular connectivity was set up in the ewes' paddock(s) with a mineral lick used as the attractant. Lambing occurred from 30 April to 16 May 2021. All the ewes were held together from conception to one month prior to lambing when they were split into 3 mobs according to pregnancy status (single, twin, triplet). All lambs were identified and weighed at birth and at weaning at 21 weeks from the start of lambing. This information was used to classify each ewe according to the number of lambs weaned (NLW from 0 to 3; Fig. 1). Average live weight (LW) throughout the trial was calculated for each group using a linear mixed-effects model with ewe as a random factor and date and NLW as fixed effects with R Studio.

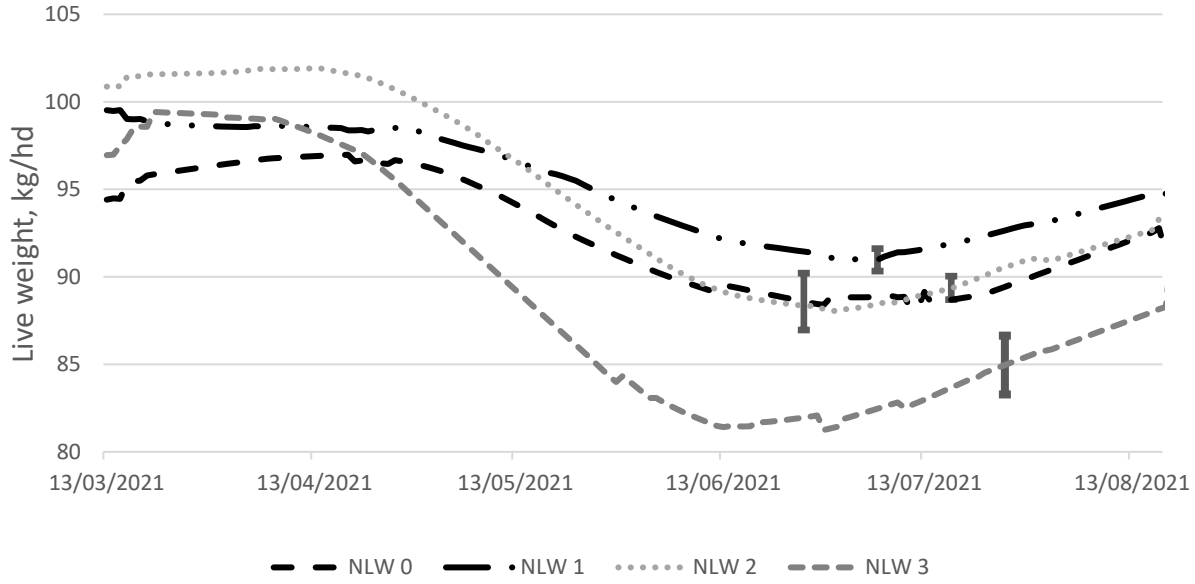

Fig.1. Live weight of Poll Dorset ewes in late gestation and lactation according to the number of lambs weaned (NLW).

A significant date × NLW interaction ($P < 0.001$) indicated that temporal changes in LW were affected by the number of lambs weaned by ewes. In general, all ewes lost LW during lactation. However, ewes with 0 (n = 17), 1 (n = 307), 2 (n = 255), and 3 (n =29) NLW, respectively, lost 15.5, 16.6, 20.7 and 23.5 kg LW from pre-lambing to their minimum body weight during lactation. It was concluded that a remote monitoring walk over weighing platform was able to capture individual ewe body weight data pre- and post-lambing within a paddock environment and detect differences due to the number of lambs weaned. This information is important for producers to manage the nutrition of pregnant and lactating ewes more accurately and timely and improve survival of both ewes and lambs.

Reference

González-García E *et al.* (2018) *Computers and Electronics in Agriculture* **153**, 226–238.

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Time spent licking as a potential predictor of lick block supplement intake by grazing cattle

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The use of multi-nutrient lick blocks as supplements is commonplace to rectify nutrient deficiencies in ruminants grazing low-quality forages under harsh environmental conditions (Salem and Nefzaoui 2003). Quantifying block intake by individual cattle is pivotal to assess their supplement use efficiency and their subsequent performance response to the level of supplement being ingested. However, estimating supplement block intake by cattle at an individual animal level in commercial grazing environments is challenging. Hence, the effectiveness of block supplementation is typically evaluated on a herd basis (Simanungkalit *et al.* 2022). This experiment defined the association between daily time spent licking, as predicted by either an ear-tag accelerometer algorithm or a radio-frequency identification (RFID) system, and the intake of a block supplement by grazing cattle at the herd level.

Fourteen beef heifers (Angus [$n = 7$] and Brahman [$n = 7$] weighing [kg ± SD] 291 ± 16 and 217 ± 17 kg, respectively) were used for the study. Each heifer was fitted with a unique RFID tag enclosing a passive transponder (Allflex® Pty. Ltd, Capalaba, Queensland, Australia) on the right ear and an ear-tag containing a tri-axial accelerometer (AX3 3-Axis Logging Accelerometer, Axivity®, Newcastle Helix, Newcastle, UK) on the left ear. The heifers were spilt into two breed groups of Angus and Brahman and placed into two different yards (30 m x 30 m) for 21 days of experimental study. Each yard was equipped with an automatic supplement weighing unit (ASW) integrating an RFID system (UNE Science Engineering, Armidale, NSW, Australia), an automatic feeder (GreenFeed system®; C-Lock Inc., Rapid City, SD, USA) and a water trough. The block supplements (n = 3; 20 cm x 20 cm x 20 cm; 17 kg) were provided on the ASW unit platform in each yard, enabling multiple heifers to access the blocks simultaneously. Access to the feed and drinking water was given *ad libitum,* while access to the ASW unit was restricted to four h/day from 1600–2000 hours. Within the 4-h session, the RFID system and ear-tag accelerometer estimated individual time spent licking by individual heifers. The RFID system recorded the presence of RFID tags at a maximum distance of 50 cm from RFID reader antennas mounted 50 cm above the blocks. Concurrently, the accelerometer algorithm predicted the time spent licking at blocks by individuals. Data were analysed using Pearson's correlation test ($P < 0.001$).

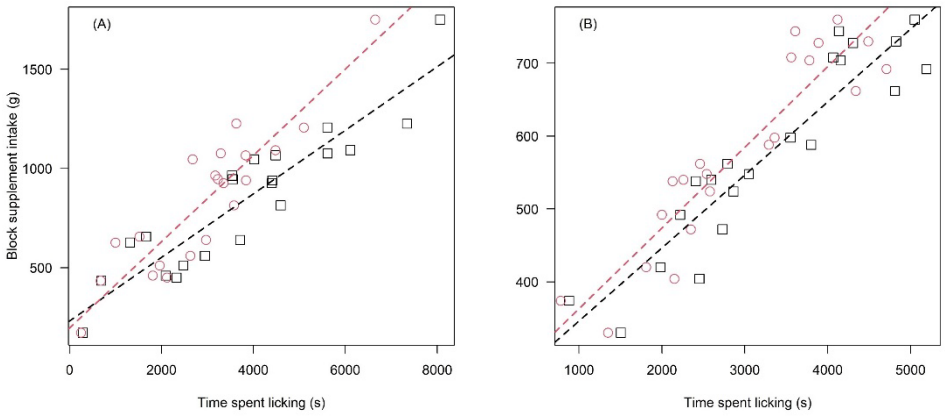

Fig. 1. Block intake related to time spent licking per day on a herd basis for Angus (A) and Brahman (B) heifers over 21 days. Points represent time spent licking predicted by RFID (□) and accelerometer (o). Dashed lines represent the regression (fitted) lines.

This study showed a significant correlation between block supplement intake and time spent licking in both Angus (Fig. 1A) and Brahman (Fig. 1B) heifers predicted by the RFID system (r = 0.92 (A), 0.93 (B); $P < 0.001$) and by accelerometer (r = 0.91 (A), 0.92 (B); $P < 0.001$). These results aligned with Imaz *et al.* (2020), who reported a significant correlation between molasses lick-block intake and feeding duration in grazing cattle recorded by an automatic feeder (r = 0.95; $P < 0.01$). Although this analysis is confounded by temporal pseudo-replication, it does suggest that time spent licking predicted by RFID system or ear-tag accelerometer could be used as a variable for predicting block supplement intake in grazing cattle for both Angus and Brahman heifers. Further research with additional replicate herds is warranted to test the validity of this hypothesis.

References

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Simanungkalit G *et al.* (2022) *Applied Animal Behaviour Science* **247**, 105543.

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Feed intake of beef cattle predicted using Greenfeed emission monitor

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Measurement of feed consumed by free-ranging cattle has historically proven difficult. The Greenfeed emission monitor® (GEM; C-Lock Inc., Rapid City, South Dakota) measure greenhouse-gas (GHG) emissions by cattle. The GEM dispenses feed pellets as an attractant to induce cattle to place their head in the machine. The aim of this investigation was to evaluate the utility of GEMs to deliver a dietary marker (Cr) in the pellet for the purpose of estimating daily faecal output (FO) and feed dry-matter-intake (DMI), and to compare results from this method with each animal's actual feed-intake and with alternate methods for predicting feed intake by cattle.

This investigation used 59 Angus cattle that underwent a 10-week feedlot feed-efficiency test described in Herd *et al*. (2019). Actual DMI by each animal was calculated as weight of feedlot ration consumed plus pellets dispensed to it by the GEM. The test ration had a DM-digestibility (DMD) of 0.7 and metabolizable-energy content of 10.3 MJ/kg DM. The GEM record all visits by animals and how much pellet is dispensed. Chromic oxide was incorporated into the pellet during manufacture. The cattle were weighed fortnightly and samples of faeces collected. Not all the cattle used the GEM regularly enough for the purpose of calculating GHG emissions so 41 animals previously identified as having sufficient records ($N \geq 30$) were studied. A further subset of 30 animals with ≥70 GEM records and another of 22 animals with ≥100 GEM records were also investigated. Samples of the feedlot ration, GEM pellets and faeces were dried and then the Cr-concentration determined using portable X-ray fluorescence (pXRF) spectroscopy. Cr-counts determined by pXRF were used in subsequent calculations without conversion to Cr-concentration.

Daily FO (kg DM/d) was calculated as Cr-dose/faecal-Cr, where faecal-Cr is the average of Cr-counts for five faecal samples collected over the test. Daily DM-intake (DMI; kg/d) was calculated as FO/(1–DMD). Two predictions of DMI using the labelled pellets were calculated: pPellet1 which used the value of 0.70 for DMD, and pPellet2 which used each animals own DMD determined separately (Herd *et al.* 2019). Alternate predictions of DMI were calculated using the Australian feeding standards (pSCA; SCA 2007), literature prediction based on bodyweight (Wt) and Fat (pLiterature; Herd *et al*. 2019), and from models described in Herd *et al*. (2021) derived from different Angus cattle measured in the same research feedlot: model 3 using Wt and Fat (pWt&Fat); model 5 using expired carbon-dioxide (pCO2); and model 9 (pWt&CO2).

The correlation of actual DMI with either marker-based prediction increased with more GEM records, but the slopes of the regressions were less than unity (Table 1). The correlation of DMI with DMI predicted from SCA, Literature and Wt&Fat did not increase with more GEM records and the slopes of the regressions were less than unity. The correlations of measured DMI with DMI predicted from CO2 and Wt&CO2 were generally greater than for the alternate methods, were less sensitive to number of GEM records and their regressions were not different from unity. Actual DMI by the subset of 22 animals was 12.1 ± 1.3 (mean ± SD) kg/d, being under-estimated ($P < 0.01$) by pWt&CO2 (11.0 ± 0.7 kg/d), but not ($P > 0.05$) by the other six predictions for DMI.

Table 1. Correlation coefficients (r-values[A]) and regression coefficients (b-values[B]) for actual DMI with seven alternate predictions of DMI with increasing numbers of GEM records

Number of GEM records	Number of animals		Pellet1	Pellet2	SCA	Literature	Wt&Fat	CO2	Wt&CO2
30 or more	41	r	0.33*	0.25^{ns}	0.24^{ns}	0.31*	0.49**	0.52**	0.60**
		b	0.11	0.08	0.21	0.30	0.53	**0.77**	**0.75**
70 or more	30	r	0.57**	0.55**	0.17^{ns}	0.33^{ns}	0.49**	0.45*	0.54**
		b	0.20	0.20	0.15	0.34	0.59	**0.77**	**0.84**
100 or more	22	r	0.65**	0.62**	0.22^{ns}	0.30^{ns}	0.46*	0.55**	0.62**
		b	0.29	0.29	0.21	0.31	**0.57**	**1.13**	**1.10**

[A] $^{ns}P > 0.05$; $*P < 0.05$; $**P < 0.01$. [B]Values in bold do not differ from 1 ($P < 0.05$).

This investigation demonstrated that GEM can be used with labelled feed pellets to predict DMI that is linearly correlated with actual DMI. This investigation also demonstrated that multiple short-term breath measurements by GEM can predict feed intake with greater accuracy and less bias than methods based on Wt and body composition data alone. This application of GEM is particularly suited for daily prediction of feed-energy intake by free-ranging cattle.

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Ruminal fluid preservation for *in vitro* gas production systems

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The *in vitro* gas production techniques require ruminal fluid to simulate the digestion process of feeds in the rumen (Getachew *et al*. 2004). However, the availability of ruminal fluid regularly is limited due to high management costs, ethical issues and facility requirements for maintaining rumen fistulated animals (Denek *et al*. 2010). Storing ruminal fluid while maintaining its microbial activity is a potential approach that would enable the standardisation of *in vitro* studies by decreasing variation and reducing the need for frequent access to cannulated animals on research farms (Luchini *et al*. 1996). Therefore, it would be beneficial to preserve ruminal fluid in adequate quantity for subsequent *in vitro* feed degradation studies. Using a batch gas production system, the present experiment evaluated a series of ruminal fluid preservation techniques for their use in *in vitro* feed fermentation.

A factorial design was used to compare two substrates (lucerne hay vs. wheat grain) and four preservation techniques relative to fresh ruminal fluid: (1) frozen at –20ºC; (2) preserved using 5% dimethyl sulfoxide (DMSO) and frozen at –20ºC (D-20ºC); (3) snap-frozen using liquid Nitrogen and stored at –80ºC (–80ºC); and (4) preserved using 5% DMSO, snap frozen in liquid Nitrogen and stored at –80ºC (D-80ºC), over five incubation periods (1, 4, 8, 14 and 30 days). All data were statistically analysed using unbalanced ANOVA using GenStat V18 package.

The mean cumulative gas production of wheat grain (84.5 mL/g) and lucerne hay (54.9 mL/g) incubated with fresh ruminal fluid did not differ ($P > 0.05$) from the gas production using ruminal fluid preserved at D-20ºC (90.1 mL/g and 55.0 mL/g respectively). The time at maximum rate of gas production from fresh ruminal fluid was also not different ($P > 0.05$) from ruminal fluid mixed with D-20ºC for both substrates. The concentration of acetic acid, propionic acid, and iso-butyric acid did not differ ($P < 0.001$) between fresh ruminal fluid and the D-20ºC. Incubated substrates produced higher average ammonia-N values ($P > 0.05$) when fermented with fresh ruminal fluid than a preserved ruminal fluid, except for –80ºC.

Table 1. Effect of feed stuff (wheat grain vs lucerne hay), ruminal fluid storage conditions (Fresh vs –20°C and –80°C), dimethyl sulfoxide (DMSO) addition (0 vs 5% DMSO) on fermentation parameters[A]

Feed (F)	Wheat grain					Lucerne hay					SED[B]	*P*-value
Storage (S)	Fresh	–20°C		–80°C		Fresh	–20°C		–80°C			
DMSO (D)		–	+	–	+		–	+	–	+		
Gas production (mL/g)	84.5^{a}	66.5^{c}	90.1^{a}	73.2^{b}	73.5^{b}	54.9^{d}	41.0^{e}	55.0^{d}	46.5^{e}	62.4^{c}	6.18	0.001
Time at max. rate (h)	7.49^{b}	7.01^{cb}	8.29^{b}	7.75^{b}	5.77^{d}	8.11^{b}	7.79^{b}	8.11^{b}	12.5^{a}	8.70^{b}	1.584	0.001
Ammonia-N (mM)	0.30^{d}	0.15^{e}	0.15^{e}	0.34^{d}	0.18^{e}	0.99^{a}	0.74^{b}	0.58^{c}	0.90^{a}	0.60^{c}	0.096	0.001
Acetic acid (mM)	59.9^{cd}	71.3^{ab}	56.9^{d}	75.5^{a}	70.9^{ab}	50.6^{e}	68.3^{b}	49.8^{e}	60.8^{cd}	64.5^{bc}	5.70	0.001
Propionic acid (mM)	32.3^{c}	43.3^{a}	28.8^{cd}	39.6^{a}	41.0^{ab}	17.8^{e}	37.3^{b}	27.3^{d}	38.8^{b}	32.4^{c}	3.93	0.001
Iso-butyric, (mM)	1.77^{c}	3.13^{bc}	3.25^{bc}	3.44^{bc}	5.43^{a}	0.91	4.19^{ab}	2.55^{bc}	4.93^{a}	5.65^{a}	1.770	0.05

[A]All measures taken after 24 h of fermentation and pooled across day of treatment.
[B]Standard error of the difference for Feed (F) x Storage (S) x DMSO (D).
Row-wise superscripts indicate different treatment means ($P < 0.001$).

This experiment indicated that all preservation techniques examined produced measurable values for all parameters despite showing a reduction over time. The preservation of ruminal fluid using D-20ºC produced gas production results with the least difference compared to fresh ruminal fluid and thus appear to be a more reliable preservation technique to adopt for feed ranking purposes when access to fresh ruminal fluid is limited. Preservation at –80ºC can also be used without significant loss of ammonia-N, indicating a potential for use in *in vitro* protein quality assessment experiments.

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Small Ruminant Spatial Landscape Distribution in Queensland Australia: a case study of sheep and goats co-grazing

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Small ruminant landscape distribution and grazing management are becoming more important issues as the sheep and goat industry in Western Queensland continues to grow. The industry is interested in understanding how sheep and goats use the landscapes in which they graze and how this might be optimized in terms of productivity and sustainability. The objective of this study was to evaluate spatial movement patterns of Dorper sheep and rangeland goats in a case study paddock.

The Dorper sheep and rangeland goats co-grazed on the same pasture near Longreach, Queensland. Global positioning system (GPS) tracking collars were placed on a sample of the sheep and goats from the beginning of August 2019 until mid-March 2020. The GPS units recorded locations every 10 min, however not all GPS collars successfully recorded locations for the entire 8-month period. Therefore, the study period was restricted so that the analyses used tracking data for goats started on 11 August 2019 and ended 6 December 2019. The sheep data set starts 10 August 2019 and ends 31 January 2020. Tracking data from seven goats and seven sheep were used to calculate daily distance travelled, distance to water, and activity budgets. These dependent variables were compared against the daily temperature and rainfall patterns. To determine areas of high usage within the pasture, ArcMap was used to generate a hotspot analysis of the sheep and goat locations on the pasture.

Dorper sheep travelled an average of 5.6 km/d with a maximum of 11 km of travel each day. Goats travelled an average of 5.6 km with a maximum of only 9.1 km/day. Throughout the entire study both goats and Dorper sheep were an average of 0.8 km from water, with a maximum distance from water of 2.4 km for Dorper sheep and 1.9 km for goats. Both the sheep and goats were active for about 45% of the day. A hotspot analysis of the GPS tracking data showed a higher concentration of sheep and goats near water sources (Fig. 1). As the maximum daily temperature increased, sheep and goats remained closer to water ($P < 0.05$). The maximum distance Dorper sheep travelled from water decreased as minimum daily temperature increased ($P = 0.02$).

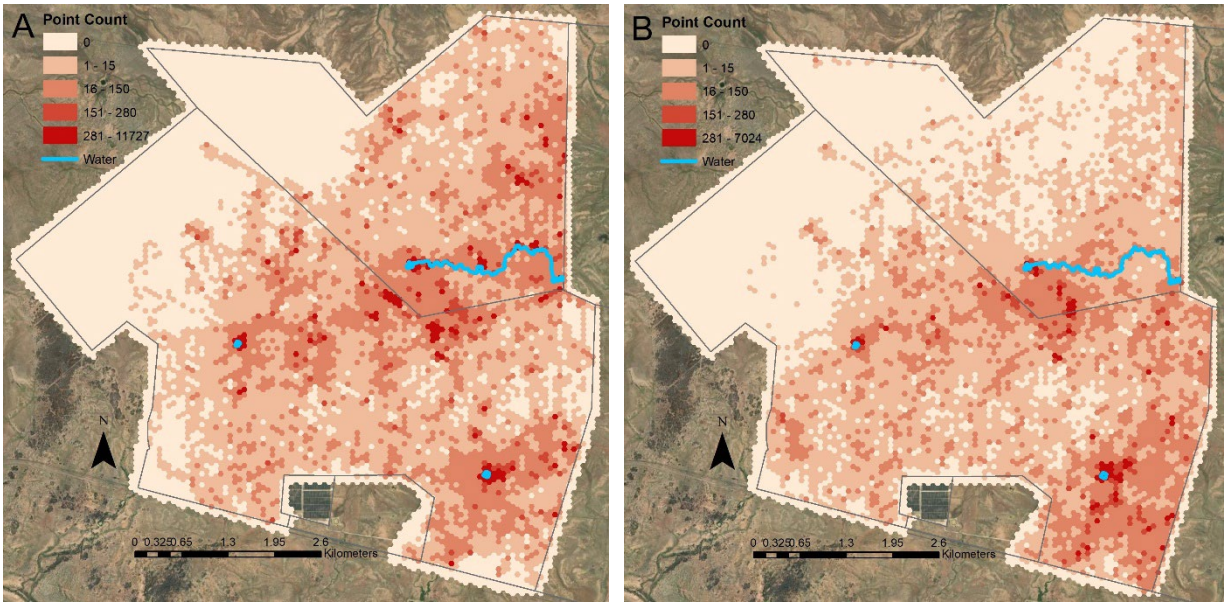

Fig. 1. ArcMap image of the pasture with hotspot analysis for (A) Dorper sheep and (B) rangeland goats GPS point counts.

Past studies have shown variable results regarding small ruminant landscape distribution, with average daily distance travelled ranging between 3.2 km/day and 8 km/day for sheep (Lynch, 1974; Squires 1974). The current study provides more updated and precise information on sheep and goat movement across rangelands. Understanding small ruminant distribution in extensive rangeland pastures helps managers to determine optimal places to develop new water sources and implement new fences to control grazing pressure to improve landscape productivity and sustainability.

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Walk-over-weigh and drafting technologies can increase the validity and value of on-property cattle research

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For the future of extensive grazing systems to be more profitable and sustainable at the farm level, the industry needs to find better ways to evaluate new tools, products, and practices for cattle producers. The diversity in property management and geography predicates significant differences in on-farm outcomes between sites when trialling new interventions, yet costs are often prohibitive to conduct widescale assessments that consider multiple production systems and bioregions. A potential solution to this problem is enabling producer-led research that has sufficient scientific rigour to derive valid outcomes, both within and across properties. Trials designed using traditional data capture and observation methodologies are constrained by data resolution, confounding factors, excessive capital and labour requirements. New-to-market precision technologies may assist, for example, walk-over-weigh (WoW) and auto-drafting technologies provide an opportunity to continuously monitor performance and remotely manage individual cattle (Dickinson *et al.* 2013), while Global Navigation Satellite System (GNSS) and accelerometer sensors can be deployed to monitor grazing preferences following an intervention (Bailey *et al.* 2021). Leveraging these technologies, researchers and producers can mitigate issues associated with traditional experimental methods.

The objective of the current study was to determine whether WoW and drafting technologies can provide useful and accurate data in producer-led experiments. To do so, a supplement trial was undertaken in an on-property setting at Belmont Research Station. Thirty-two heifers, stratified by weight, were randomly allocated to a treatment or control group. Treatment group heifers were offered a commercial supplement, while control cattle were given none. All heifers were housed in one paddock and were restricted to treatment or control water sources via an auto-drafter. At the commencement of the trial, cattle were naïve to in-paddock drafting technologies, therefore, a 5-week acclimation period was undertaken. The study period then ran between February and May. Liveweights were captured at each water visitation, and drafting accuracy monitored at water source exits. Daily weight data were processed to derive weekly weight values. Static weights were recorded monthly.

Drafting throughout the 90-day trial was 99.7% accurate across 18 154 events. Adjusted to week, liveweight values derived from WoW data were strongly correlated with the static weights recorded by technical staff ($R^2 = 0.978$, $P < 0.001$; Fig. 1A), demonstrating that WoW systems can provide reliable weekly mean weights. Weight was not significantly different between treatment groups when either static or WoW weights were analysed using a generalised linear mixed model (Fig. 1B). Throughout the trial, treatment group heifers were twice as likely to enter the water yard via the WoW, indicating the attractant effects of the provided supplement.

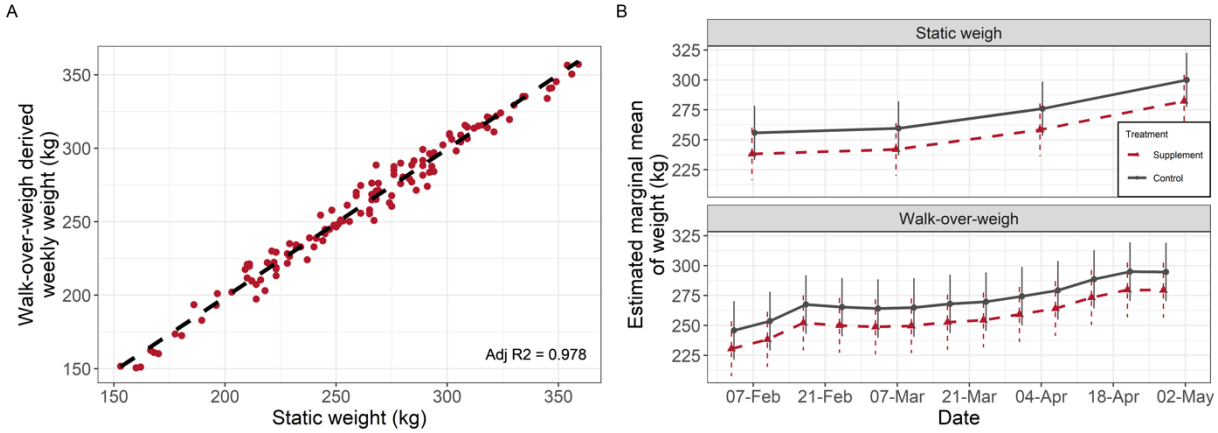

Fig. 1. Comparison of: (A) the correlation between individual and static weights, and (B) the model outcomes between the two weighing strategies.

Results from the current study support the claim that WoW and auto-drafting technologies can be used to reduce labour and decrease the risk of data entry errors in producer-led grazing research activities, particularly where regular intervention or support by research teams is unfeasible. Although cattle training is required, these technologies are scalable, accurate and provide unique opportunities to drive co-produced, applied research with cattle producers across varying landscapes and livestock systems. As the uptake of precision livestock technologies continues, we foresee a new model of data-driven, producer-led research where a collaborative effort between graziers, researchers, and the commercial sector delivers industry-scale research outcomes.

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Novel opportunities for value adding to piggery effluent

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The agricultural industry is committed to sustainable development to improve the long-term viability of businesses. As enterprises increase in size, investment in waste management technology has both environmental and economic benefits. Biogas generation systems provide opportunities for pork producers to generate energy from piggery waste and produce organic fertiliser and soil conditioners as well as reducing greenhouse gas (GHG) emissions. Exploring the novel use of surplus 'green/renewable' energy provides a pathway to enhance return on investment.

A large Queensland family-owned 1600 sow farrow-to-finish piggery funded a biogas plant in 2015 to power the lighting and environmental control systems in the piggery buildings as well as the feed mill, which produces over 13 000 tonnes of feed annually. Hot water pads installed in the farrowing rooms use the heat energy produced to enhance piglet performance. The business offsets up to 115% of their energy requirement using biogas generated at the farm.

The objective of the study was to review the production and use of energy from co-digestion of feedstocks in a biogas plant. The facility has two linked digesters with a total capacity of 6000 m^3, operating on a 30-day cycle. Piggery effluent from three production sites is piped to a 500 m^3 storage tank. Each day raw effluent (40 m^3) is mixed in a substrate tank with the locally sourced abattoir paunch then pumped to the digestor. In addition, a further quantity of effluent (160 m^3) is pumped directly to the same digestor. The digestate from the process is high-value phosphate fertiliser, high-fibre soil conditioner, and the liquid waste fraction which is mixed with fresh dam water to irrigate 100 ha for crop production.

Key performance indicators (Fig. 1a) recorded for the period July 2020 to June 2021 showed the variation in paunch supply with limited availability during the summer season abattoir shutdown. Fig. 1b, c shows that the lack of paunch changed the balance of the feedstock which impacted on the digestor operation, lowering both biogas production and the methane (CH_4) content of the biogas compared to when the primary feedstock was solely piggery effluent. The time lag in Fig. 1b, c compared with Fig. 1a is due to the digesters operating on a 30-day hydraulic retention time.

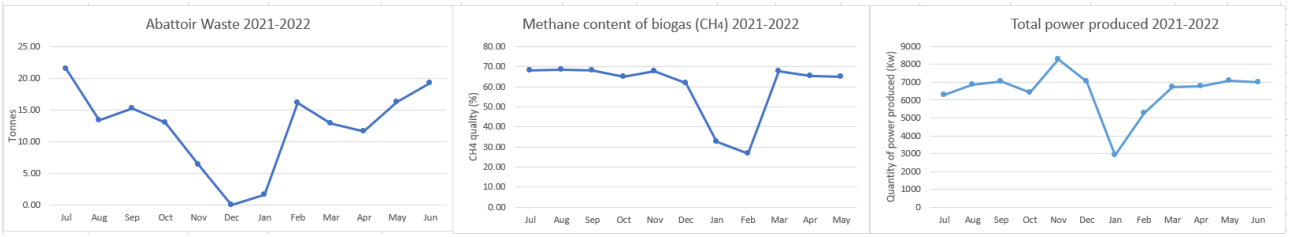

Fig. 1. Relationship between a) abattoir waste delivered to farm, b) methane content of biogas and c) total power output.

The use of co-digestion in anaerobic digestion systems assists CH_4 yields as positive synergisms are established in the digestion medium, and missing nutrients are introduced by the co-substrates (Chow *et al*. 2020). Other feedstock choices for co-digestion include food waste that never leaves farms, food that is lost during transport, or food waste from the retail and hospitality sectors. Food waste that costs the Australian economy $20 billion/year (Australian Government 2017) can have maximum CH_4 producing capacities exceeding 700 m^3 CH_4/tonne of volatile solids (VS) compared with piggery effluent at 450 and abattoir paunch at 470 m^3 CH_4/tonne VS (Commonwealth of Australia 2019). Diverting food waste to anaerobic digestion would turn a cost into an opportunity, generating revenue from energy production and co-products and potentially reducing GHG emissions from other sectors of the economy.

When electricity supply exceeds farm demand, up to 100 kW of power is donated to the national grid. Previously, biogas surpluses were flared but now a feasibility study is evaluating an additional income stream. Selling power to drive high energy-demanding cryptocurrency mining terminals could return over $100 000/year. The number of terminals is constrained by the amount of electricity generated which is limited by the amount of feedstock available to fuel the plant.

The results indicate that the co-digestion of feedstocks with consistent supply improves CH_4 quality and yield. The performance of the biogas plant is currently constrained by a shortage of abattoir waste during the summer season shutdown. Cooperating with others in the food supply chain to source a consistent supply of food waste would increase biogas yield significantly and allow an increase in the mining of bitcoin and the exploration of other novel opportunities.

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Sensor-based livestock traceability – linking emerging on-animal tracking technologies with livestock health and meat quality outcomes at processing

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Traceability of livestock is more important than ever before. Consumers are increasingly interested in where their food comes from and how it is produced; and the risk of disease outbreaks among livestock pose major impacts to livestock industries. Regulators are interested in improving the resolution at which animal location data is collected and are also keen to establish how emerging technologies might improve traceability systems (Trotter *et al.* 2018).

In Australia, the current National Livestock Identification System offers whole-of-life identification and tracking at a property level but does not provide real-time location or behaviour data and relies on manual transfer of information into the database by producers. Within this system, livestock are typically only identified at key points in their production such as marking, transport and processing, leaving large information gaps in their monitoring. Beyond the farm, animal health and meat quality data are increasingly collected at processing and reported back to producers. However, limitations in the current traceability system and a lack of integrated and objectively measured data, make it difficult to determine where in the production of each animal interventions could have been made. Improving the current traceability system will ensure Australia's reputation for high quality products and maintain our competitiveness in the global market.

On-animal sensors (OAS; smart tags and collars; Fig. 1) pose several benefits for improving traceability in areas such as biosecurity, product authenticity and animal welfare, as well as assisting the integration of pre-farm gate data with processing data. On-animal sensors are commonly based on a GPS and/or accelerometer ear tag or collar. These technologies collect detailed information on the location, behaviour and state of the animal and have the potential for objective detection of issues related to disease state, animal temperament, nutrition and handling. Several studies have explored the use of OAS for detecting health and welfare issues in sheep and cattle such as disease, predation and birth events (Fogarty *et al.* 2020; Tobin *et al*. 2020); however, there has been little investigation of how OAS data might be linked with processing data.

The broad objective of this project is to determine whether OAS will be useful in a traceability capacity in the beef value chain. The aims of the study are to (1) determine whether OAS data can help predict meat quality (e.g. high pH and subsequent dark cutting) and animal health (e.g. liver fluke) issues that might show up at processing; and (2) determine whether linked OAS data and abattoir data could help inform producers where intervention strategies could be implemented.

A case study deployment of up to 200 OAS on at least one commercial beef enterprise will be conducted. Cattle will be tracked for up to 12 months prior to processing. The OAS data will be used to generate a range of objective measures of animal behaviour and management which can be linked to processing outcomes.

This study will provide valuable information about how OASs could be used to improve traceability of livestock through the red meat value chain. In particular, the results will determine how OAS data can be linked with meat quality and health data at processing to improve future management and production of livestock.

Fig. 1. A Smart Paddock Pty Ltd ear tag and collar fitted to a heifer at Central Queensland University.

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Monitoring time between calving and return to water in a Northern Territory breeder herd

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Little is known about cow behaviour in the time immediately following a calving event in extensively managed beef herds in northern Australia. This is mainly due to large herd and paddock sizes, and limited opportunity for observation, particularly during the wet season (November to April). The objective of this study was to monitor and record cow behaviour and calving events on an extensive property in the Northern Territory.

Two hundred confirmed pregnant Brahman and Brahman-Senepol cross mixed age cows were monitored on Manbulloo Station, Northern Territory during the 2019 calving season (September to December). The paddock was approximately 22 km^2 and water was available at all times from a trough located in one corner of the paddock. Cows were monitored using birthing sensors and GPS tracking collars (Schatz *et al.* 2021). The birthing sensors sent an alert when expelled immediately before calving, and the GPS collars recorded location every 15 min. This enabled the cow and calf to be observed shortly after birth, and the cow's location and movements to be monitored, including identifying when cows first went to the water trough after calving. This study was approved by an ethics committee.

Rainfall in 2019 was significantly below average, resulting in no alternate water sources available in the paddock other than the trough during the calving season. The first significant rainfall occurred on 28 November and time off water was not monitored beyond this date as surface water was then available in the paddock. During the calving season maximum temperatures were above average (average = 39.7°C, max = 42.7°C). Technical difficulties encountered included a number of birthing alerts not being received and some collars not sending regular GPS fixes. As a result, only 50 cows had sufficient data to calculate time off water following calving. Cows that calved within 250m of the trough (n = 3) were classed as calving at a water point and time off water was allocated as 0hrs. The maximum time off water recorded during the observation period was 46hrs 34mins, with an average time of 20 h 3 min (± 10 h 26 min) (mean ± SD) (Fig. 1). Calving locations were distributed throughout the paddock. The average distance of calving location from water for these 50 cows was 2.6 km, maximum distance was 5.7 km. A regression analyses was performed to analyse distance from water of a calving event versus time to return to water, while the P-value was significant ($P < 0.001$), the R^2= 0.32 indicating the relationship was not strong. In conclusion, cows can spend an extended period of time away from water following a calving event, even when temperatures exceed 40°C. The new technology used in this study enabled collection of information to improve the understanding of cow behaviour during calving in extensive northern environments. This may be helpful in devising strategies to reduce calf loss in extensive northern beef herds.

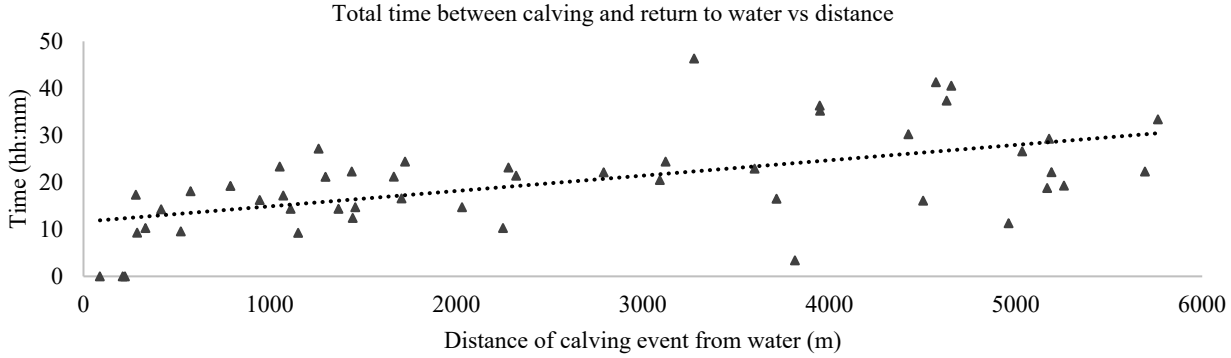

Fig. 1. Observed time from calving to return to water in September to November 2019 compared to distance of calving event from water (with regression model).

Reference

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Performance of heifers divergent in RFI-feedlot EBVs grazing mixed perennial temperate grasses

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Most of Australia beef cattle are run extensively on pastures, without supplementation. Thus, increase in productivity can be achieved by improved efficiency at pasture. Our research is evaluating performance at pasture of Angus heifers selected on the basis of their estimated breed values (EBVs) determined from their genomic EBVs and their midparent EBVs for residual feed intake in BREEDPLAN (ABRI 2017), which are determined from feedlot data (RFI-f-EBV). Fifteen-month-old heifers (n = 32) grazed within two replicates of 16, each with 8 Low-RFI-f-EBV (High feedlot efficiency) and 8 High-RFI-f-EBV (Low feedlot efficiency) heifers was used in this study. Each replicate group grazed one of eight 0.61 ha paddocks mixed perennial temperate grasses at 7-day intervals during repeated 28-day cycles: Phase 1, 4298 kg DM/ha on offer; Phase 2, 2961 kg DM/ha on offer. Liveweight (LW) and average daily gain (ADG) were analysed by linear regression with RFI-f-EBV group (Low or High) and Phase (1 or 2) and their interaction as fixed effects. Initial and final LW did not differ between High- and Low-RFI-f-EBV heifers or between Phase 1 and 2 (Table 1). Liveweight change (LWc) and ADG did not differ between Low-RFI-f-EBV and High-RFI-f-EBV. However, ADG and LWc differed between Phases 1 and 2 (mean 250 vs –120 g, P = 0.002 and 7 vs –3 kg, P = 0.002, respectively).

Table 1. Mean liveweight, liveweight change and average daily gain of heifers divergent in residual feed intake estimated breeding values (RFI-f-EBV) for two 4-week grazing phases (Phase)

Variable	RFI-f-EBV group				SEM	*P*-value		
	Phase 1		Phase 2					
	High	Low	High	Low		RFI-f-EBV	Phase	RFI-f-EBV x Phase
Number of heifers	16	16	16	16				
Initial liveweight (kg)	359.4	351.3	367.1	362.8	4.46	0.493	0.291	0.833
Final liveweight (kg)	363.4	361.3	362.7	360.5	4.12	0.799	0.927	0.997
Liveweight change (kg)[A]	4	10	–4.44	–2.31	1.77	0.226	0.002	0.562
Average daily gain (g/d)[A]	143	357	–158	–82	63.21	0.226	0.002	0.563

[A]Calculated from difference between initial LW and final LW; standard error of the mean (SEM).

This study demonstrated that there was a significant difference due to Phase. Heifers gained 7.0 kg LW in Phase 1 while in Phase 2 heifers lost –3.4 kg (P = 0.002). The LW loss coincided with pasture on offer, DM, dry matter digestibility, metabolisable energy (4298 vs 2961 kg/ha, P < 0.001; 44.9 vs 53.6%, P = 0.001; 45.2 vs 42.4%, P = 0.024; 6.16 vs 5.69 MJ/kg DM, P = 0.027; for Phase 1 and 2, respectively). This resulted in a higher pasture disappearance, expressed as % of LW/head/day in Phase 1 than in Phase 2 (2.07% vs 1.71%, SEM 0.09, P = 0.042). The decline in pasture availability and nutritional quality as grazing progressed was also found in a similar study with heifers grazing drought affected pasture (Alvarenga *et al*. 2021). There was no evidence that the variation on RFI-feedlot EBVs from Angus heifers affected their performance when grazing mixed perennial temperate grasses. However, pasture availability and quality significantly influenced LWc and ADG. These results are being assessed in conjunction with in-field walk-over-weighing, CSIRO eGrazor sensor collars, and pasture mapping to develop methods for more comprehensive assessment of grazing efficiency.

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Sheep production in Samoa: a snapshot of the industry

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The history of sheep production in Samoa is relatively young with the first official recordings registered in the 2009 agricultural census (SBS 2021) with 249 animals in the whole country. The national sheep flock has significantly increased to 1,654 animals within the time span of 10 years (SBS 2021). However, its estimated that the great majority (>90%) of sheep meat consumed in the country is still dominated by frozen imported products (Cowley *et al.* 2019). This study aimed to investigate the main characteristics of the sheep industry in Samoa in order to better identify possible gaps for improvement. The main hypothesis of this study is that there will be structural and practice differences between farmers from the two main island in Samoa (i.e. Upolu and Savai'i) and also that there would be a high level of gastro-intestinal nematodes burden in sheep flocks.

The characteristics of sheep production was assessed by a survey deployed in Upolu and Savai'i islands. In each island 25 farmers were interviewed (Fig. 1) which represents 25% and 47.1% of the total households currently raising sheep in Upolu and Savai'i respectively (SBS 2021). The farms were randomly selected using a registration databased developed by the Samoan Ministry of Agriculture and Fisheries. The survey was developed and applied using the CommCare platform, the survey was composed of 143 qualitative and quantitative questions. Data collection was conducted in person between the 1 November and 9 December 2021. During the visit of each household, faecal samples were collected directly from the rectum of adult animals (n = 10; ewes and rams) as well as growers (n = 10; lambs and weathers). Samples were kept at 4°C until analysed for faecal egg count (FEC) by modified McMaster technique. Summary statistics and mapping was conducted using the open software R (R Core Team 2019) and the package *ggmap* (Kahle and Wickham 2013).

In general, very small differences were observed when comparing the structure of sheep farms in Upolu and Savai'i (Table 1). The average area of farms varied between 3.0 and 3.9 ha and the flocks between 12.1 and 15.8 for Savai'i and Upolu respectively. The majority of sheep famers also reported to raise cattle as well as to grow agricultural crops in both islands. Approximately half of the Samoan farmers reported to have improved pastures and within the farmers who reported to have improved pasture the most common species was *Setaria sphacelate* present in 68% of the properties. A small proportion of farmers record of flock information (12–24%) and own an animal scale (4.5–20.8%) but the majority have an animal house (80–96%). However, a great variation in quality of the animal house infrastructure has been observed in the field. Only 8% of famers interviewed reported to practice weaning of lambs. The FEC showed a very low level of gastrointestinal nematodes contamination without great differences between locations and animal classes.

Table 1. Descriptive parameters of sheep farms in Samoa

	Savai'i (n = 25)	Upolu (n = 25)
Total area (ha)	3.0	3.9
Flock size (head)	12.1	15.8
Farms that own cattle (%)	63.6	58.3
Farms that also have crops (%)	68.2	62.5
Improved pastures (%)	45.5	45.8
Record flock info. (%)	12	24.0
Own animal scale (%)	4.5	20.8
Own animal house (%)	96	80
Practice weaning (%)	8	8
FEC adults	52.2	170
FEC growers	68.2	73.1

FEC, faecal egg count.

This study surveyed a large proportion of sheep raising households and therefore seems to be an overall good representation of the sheep industry in Samoa. The preliminary results suggests that contrary to our initial hypothesis the level of gastrointestinal nematodes seems to be low and doesn't seem to be affecting overall productivity of flocks. Increments in productivity may be achieved by introduction of weaning as well as the practice of weighing allied with data recording and analysis as a tool to assess farm productivity.

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Back to basics – the importance of understanding ewe joining practices

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The reproductive potential of the ewe is driven by many factors, including but not limited to, breed, joining season and nutritive status across the reproductive cycle. The current guidelines for ewe management are predominantly based on research with the Merino breed (Lifetime Wool 2006) with some research outputs extended to Maternals (first-cross ewes) (Blumer *et al*. 2019). In contrast, Composite and shedding (e.g. Dorper and Australian White) breeds have had little research. The current management guidelines emphasise body condition score (BCS) at lambing and during lactation. There is evidence that the effect of joining BCS on progeny birthweight differs between non-Merino and Merino breeds (Hocking Edwards *et al*. 2019). Progeny birthweight is highly correlated with perinatal lamb survival, and as such is a key driver of reproductive output. At an enterprise level, optimum nutrition is essential to avoid reproductive deficits caused by under or over nutrition and mitigate unnecessary supplementary feed costs (Blumer *et al*. 2019).

To build on current guidelines and assist sheep producers to achieve highly productive and profitable systems, it is essential to further understand current practices across various enterprise types. The objective of this study was to explore the joining management practices across producers of different sheep breeds and determine fundamental differences.

Commercial producers of Composite, Maternal, Merino and shedding ewes (average sample size = 526 +/–129.6 s.d.) across NSW, Vic. and SA answered a questionnaire based on ewe flock management practices via telephone interview. The study was approved by the Charles Sturt University Human Ethics Committee (Protocol number H21037).

Fifty-two producers took part in the questionnaire and joined ewe flocks between spring 2020 and autumn 2021. The most common management practices around ewe replacement type, flushing practices, ewe age at first joining and ideal joining condition are displayed in Table 1.

Table 1. The most common ewe management practices of Composite, Maternal, Merino and shedding breed sheep producers reported in a survey. Number of respondents using the most common practice is indicated in parentheses

Management practice	Composite	Maternal	Merino	Shedding
No. of respondents	16	10	22	4
Replacement type[A]	Self (16)	Purchase (6)	Self (21)	Self (4)
Flush length	2 weeks (8)	8 weeks (5)	2-4 weeks (8)	4 weeks (4)
Age of first joining	7-9 months (15)	7-9 months (7)	12-18 months (19)	7-9 months (4)
Ideal BCS at joining[B]	3.0-3.5 (7)	No trend	3.0-3.5 (13)	≤ 3.0 (2)

[A]'Self' refers to a self-replacing ewe flock and 'Purchase' to purchased replacement ewes.
[B]BCS performed according to Russel (1984).

The management practices of Composite and Merino producers were similar except for joining age. Maternal flocks commonly purchased replacement ewes while all other breeds were self-replacing. When exploring self-replacing Composite versus purchased Maternal ewe flocks, time of lambing and lamb sale weight influenced which breed was most profitable (Young *et al*. 2010), which is likely to also influence the profitability of Merino and shedding breed systems. A broad range of flushing practices were reported.

A BCS of 3.0 at joining was a relative benchmark across most enterprises. Composite and Merino producers aimed for a BCS of 3.0–3.5 at joining. The Maternal producers reported a range of joining BCS targets from no target, BCS ≤ 3.0, BCS 3.0–3.5, weight-based decisions and a 'rising plane' of condition. Lifetime Wool (2006) recommends a BCS of approximately 2.7 and above for Merinos, while Maternal guidelines recommend a joining BCS of 3.8–4.2 (Blumer *et al*. 2019), which is greater than any of the BCS targets reported. Very few shedding producers were captured, therefore drawing conclusions is inappropriate.

Further exploration into the knowledge base and drivers of these management practices is required and may provide greater understanding of differences and similarities in sheep management between breeds.

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Australian rosella (*Hibiscus sabdariffa*) by-products as a potential feed supplement for beef cattle: *in vitro* digestibility and antioxidant capacity assessment

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Hibiscus sabdariffa (L.), commonly known as rosella or hibiscus, is an annual herbaceous shrub that features brilliant crimson edible calyces. In addition to being a good source of several vitamins, minerals, and phytochemicals, its unique organoleptic properties have seen increasing demand for rosella in the Australian food industry. The calyces are harvested for human consumption, with the seed pods often discarded as a waste by-product. Given that the pods can comprise around half of the total produce harvested, there is a significant amount of nutrient-rich waste that could potentially find use as a livestock feed supplement. Our objective was to investigate the nutritional potential of rosella pods for beef cattle by conducting an *in vitro* assessment of their digestibility, and measuring the resulting simulated gastrointestinal fluid for antioxidant capacity and phenolic content, then comparing these values to those obtained using a commercially available feedstock

The *in vitro* digestibility analysis was conducted on samples of dried rosella pod (n = 3) and grain-based commercial feedstock (n = 3) substrates using a modified rumen/pepsin digestion method (Tilley and Terry 1963). Rumen was obtained post slaughter and was an aggregate of samples from a group of 28 Brahman (*Bos taurus indicus*) cross steers (live weight 706 ± 12 kg), reared on a free-forage diet consisting primarily of purple pigeon grass (*Setaria incrassata* cv. Inverell). After completion of the digestions, the resulting simulated gastrointestinal fluid was filtered and stored before recovering the digested substrates for digestibility measurements. This fluid was subjected to colorimetric ferric reducing antioxidant power (FRAP) and total phenolic (TP) assays (Johnson *et al.* 2020). Data were analysed using independent t-tests in IBM SPSS (v26).

There was a significant difference in dry matter ($P < 0.001$; Table 1) and organic dry matter ($P < 0.001$) digestibility between the rosella pods and commercial feedstock. Although the grain-based feed measured much higher in digestibility, the dry organic matter digestibility of rosella pods (58.24%) places it directly in the centre of the quality range for typical Australian hays and silages (Kaiser and Piltz 2004). There was also a significant difference in the FRAP of the simulated gastrointestinal fluid ($P = 0.02$) between the two feed substrates, but not in the levels of total phenolics ($P = 0.72$). It appears rosella pods release significantly higher levels of antioxidants during digestion when compared to the grain-based feed.

Table 1. Digestibility, Ferric Reducing Antioxidant Power (FRAP), and Total Phenolics (TP) data for the rosella pod and commercial feedstock samples (on a dry weight basis)[A]

	Rosella pods	Commercial feedstock	*P*-value
In vitro dry matter digestibility (%)	63.32 ± 0.87	78.89 ± 2.98	<0.001
In vitro dry organic matter digestibility (%)	58.24 ± 1.60	79.84 ± 2.06	<0.001
Simulated gastrointestinal fluid FRAP (mg TE/100g)	167 ± 50	0 ± 71	0.02
Simulated gastrointestinal fluid TP (mg GAE/100g)	244 ± 93	220 ± 55	0.72

[A]Values given as mean ± SD (n = 3 replicates for each). Threshold for significance of $P < 0.05$.

It was concluded that although rosella pod digestibility was lower than a conventional grain feedstock, it was comparable to the typical digestibility of most Australian hays and silages. Given the higher levels of antioxidants released during digestion, rosella waste product could potentially be added in small amounts as a feed supplement, with the added benefit of providing enhanced free radical-quenching ability to the livestock. There is a need, however, to further investigate metabolisable energy and the absence of anti-nutritional compounds, as well as palatability, to confirm the efficacy of pod use as a feed supplement. This study provides evidence for the further investigation of the use of rosella waste as an animal feed, which would improve sustainability in agriculture as well as potentially improve animal health.

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Strategies for profitable beef production with Holstein steers

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Utilising dairy breeds and genotypes into the Australian beef supply chain is well established. Indeed, in other parts of the world dairy genetics are routinely used to supply various sectors of the beef supply chain. In Australia cull cows are used for manufacturing segments of the supply chain but the use of dairy and dairy beef cross animals into premium markets has been less common. Discrimination against dairy breeds when compared to beef breeds has been widespread whether it has been through the saleyards and open auction system or via direct consignment to meatworks. Visual conformation and appearance at saleyards is taken as an indicator of low carcass meat yield, and a reason for price discounting. Similarly, some processor grids have a payment emphasis on butt shape and perceived a linkage to low meat yield, resulting in a lower price for dairy derived carcasses. Subsequently, management of surplus dairy calves has been an issue for Australian dairy farmers. Changing consumer and market expectations with regards to surplus calf management and current favourable market conditions within the beef industry has prompted renewed interest in the use and opportunity for dairy animals to be placed into traditional beef supply chains.

A desktop study outlined potential market pathways for dairy beef. Management and feeding strategies were developed for surplus dairy calves to produce a high-quality end-product suitable for the Meat Standards Australia (MSA) graded domestic beef market. Twenty-seven males with an average starting weight of 182 kg were used in an un-replicated development trial conducted at the Gatton Research Dairy. The trial comprised entire males (n = 6), castrated males (n = 10) and castrated males treated with a hormonal growth promotant (HGP) (n = 11). Animals were fed a high energy feedlot style ration in bunks aiming to increase muscle growth and fat cover relative to frame. A cost of $500/head was assumed to rear each calf to 180 kg liveweight. These costs included feed, health, mortality, freight, equipment, fuel and labour which were assigned to each calf. Growth performance and profitability of each group is outlined in Table 1.

Table 1. Processing and profitability of three groups of male calves from Gatton Research Dairy 2021 (LW, liveweight; HSCW, hot standard carcass weight; LMY, lean meat yield; MSA, Meat Standards Australia)

Group	Final LW (kg)	Dressing (% LW)	LMY (% HSCW)	MSA Index	Price ($/kg HSCW)	Cost ($/unit)	Value ($/unit)	Profit ($/unit)
Entire males	631.7	51.3			5.10	1654.00	1651.21	–2.79
Castrated males	560.4	50.2	60.8	59.8	6.51	1530.00	1804.48	274.48
Castrated males + HGP	588.7	50.4	59.8	54.9	6.45	1586.00	1912.06	326.06

The 21 steers were processed through a local abattoir within a MSA grid achieving 100% MSA compliance, compared to the corresponding Queensland average compliance of 94%. In addition, MSA index scores for both the HGP treated and the non-HGP steers were higher than the Queensland average (2.5 and 1.0 points higher respectively). The distribution of the MSA index for the steers were also very tight, indicating a high level of consistency between the steers processed. The six bulls are currently ineligible for MSA grading and as such were processed through a standard grid.

Liveweight gain was higher than reported averages of 1.2 kg/day from commercial feedlots and research trials (Rust *et al.* 2006) for all groups, with bulls achieving 1.56 kg/day; castrated males 1.37 kg/day and HGP treated castrated males 1.49 kg/day. Bulls were also the most feed efficient (kg feed/kg LW gain) at 5.72, versus 5.93 and 5.83 for castrated and HGP treated castrated groups. HGP treated steers were the most profitable group due to a higher market price compared to bulls and higher growth rates and better feed efficiency compared to non-HGP steers. A higher price for the bulls could have been obtained through processing at an alternate abattoir resulting in a profitable outcome for these animals as well.

With record beef prices and drought induced supply issues within the Australian beef industry, opportunity exists for a long-term market for the dairy and dairy cross animals within Australia's premium beef markets. Production from dairies and therefore production of calves tends to be less adversely affected by drought when compared to extensive beef operations. Dairy systems can therefore ensure stable supply into beef markets. This demonstration trial has shown the ability of Holstein steers to effectively and profitability meet MSA and higher end market grading requirements.

Challenges and areas for further work and development include: current market perceptions of animal performance and carcass suitability; economic viability of the required investment in infrastructure to grow surplus calves out and the potential of dairy cross traditional beef breed animals to improve performance and market acceptance. Opportunities that exist for dairy bred animals include: alignment with traditional backgrounders and feedlots; a valuable alternate income source for dairy operations; an alternate and stable source of supply for backgrounders and feedlots; additional animals available with genetic potential to achieve premium market specifications and a potential opportunity for smaller farms to rear males to suitable specifications for backgrounders and feedlots.

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Faba beans and lupins as a winter forage option in subtropical dairy systems

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Forage crops grown for silage in subtropical dairy systems in winter in Australia are predominantly based on forage oats and barley varieties, with legumes often overlooked due to reduced yields and low dry matter content at the time of harvest. However, legumes offer potential agronomic benefits in terms of fixing their own nitrogen and leaving soil nitrogen reserves intact. In addition, they also allow for a crop rotation to be implemented resulting in herbicide breaks and disruption of disease cycles, especially cereal root diseases. These positive attributes often result in improvements in the form of increased yields and gross margins in subsequent crops. Yield increases in wheat crops following a faba bean crop of 1–1.5t/ha and increases in grain protein of 0.7–1% have been observed (Matthews *et al.* 2003). Gross margin analysis of irrigated faba beans grown as a grain crop showed a return of $353/ha compared to an irrigated wheat crop grown under the same conditions at $318/ha (NSW Agriculture Farm Budgets 2002). This improvement in returns does not allow for the nitrogen return and subsequent yield benefit available to the next crop. From a nutritional perspective, legume crops generally offer improved feed quality over cereal crops.

An unreplicated development trial was conducted at the Gatton Research Dairy unit in 2019. Two varieties of faba beans (var. Nasma and Warda) and lupins (var. Bateman and Luxor) were evaluated alongside traditional cereal crops grown under irrigation and harvested for silage (Table 1). Crops were harvested at differing times to reflect the maturity patterns between crop varieties and species, ranging from 103 days to 148 days post planting. Both varieties of faba beans yielded higher than all cereal species except triticale. The Bateman lupins also yielded well compared to the cereals. Forage quality parameters were higher on average for the legumes compared to the cereals, with lower neutral detergent fibre (NDF) and higher crude protein (CP) content. In addition, the legume crops were quicker to reach harvest maturity than the cereal crops, potentially allowing a faster turnaround in a double cropping scenario.

Table 1. Yield (t DM/ha), crude protein (CP; % DM), metabolisable energy (ME; MJ/kg DM), neutral detergent fibre (NDF; % DM) and days to harvest (DTH) of single harvest irrigated forages

Forage	Yield	CP	ME	NDF	DTH
Legumes					
Faba *b*eans (Nasma)	18.4	18.5	10.2	35.3	117
Faba beans (Warda)	18.1	18.5	9.6	37.2	117
Lupins (Bateman)	16.0	14.3	10.1	43.1	134
Lupins (Luxor)	7.7	17.6	10.5	32.5	103
Mean	15.1	17.2	10.1	37.0	118
Cereals					
Triticale (Endeavour)	19.3	13.1	10.1	48.6	148
Cereal Rye (Southern Green)	16.7	9.5	9.0	54.6	148
Wheat (Bennett)	15.7	16.2	9.9	48.6	148
Barley (Shepherd)	11.7	15.6	9.9	42.3	117
Oats (Austin)	8.7	19.7	9.9	47.4	111
Mean	14.4	14.8	9.8	48.3	134

The yield and quality attributes of the faba bean and lupin crops grown in this development trial have shown there is potential to increase both the quantity and quality of winter crops grown on farm. These legume crops add value as a break and rotational crop option, without a loss in yield, confirming their suitability to the winter cropping system. Farmers need to assess where these crops could potentially fit into their cropping program to enhance not only feed quality and quantity but also agronomic practices. Additional research needs to be conducted to evaluate palatability of ensiled crops, optimal fertiliser and planting rates to increase yield and quality as a fodder crop, optimal ensiling times and timing of harvest with regards to maturity and dry matter levels, for example faba beans mature quickly and rapid leaf loss and therefore yield losses are possible.

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The effect of reducing total dietary trace mineral content on the performance of laying hen parent stock when replacing inorganic salts with chelated minerals

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The use of trace minerals in modern poultry production has come under scrutiny by panels such as the European Food Safety Authority (EFSA) as the levels of these minerals and corresponding heavy metal contaminate manure waste which is routinely used as crop fertiliser. Previous studies have shown that trace minerals in the chelated form of metal methionine hydroxy analogue chelate (MMHAC) were able to be applied at a lower rate due to their higher bioavailability (Mananghi *et al*. 2012). Furthermore, that applying minerals in this form allowed for greater performance due to reduced dietary metal ion antagonism and competition for sites of absorption in the small intestine. In this study the aim was to follow a cohort of laying hen breeding stock to see if the removal of all trace mineral salts and replacement with a lower level of MMHAC minerals could result in similar, or greater production performance, reducing the reliance on high levels of these salts.

This study was conducted across a commercial laying hen breeder site and corresponding hatchery in the Netherlands. A total of 8797 Novogen breeders were used. The treatment and data collection period ran from 18 weeks until 57 weeks of age with key data collection points at weeks 27 and 45 when eggs were collected, stored and hatched at short and long intervals. All birds in the study were sourced to match age and management conditions across treatments. The control fed barn contained 4167 hens and 315 roosters, the MMHAC treatment barn contained 4015 hens and 300 roosters. The only difference in treatment groups was the source and amount of trace minerals zinc, copper and manganese. The control group contained a blend of inorganic salts and organic trace mineral as shown in Table 1, while the MMHAC group contained 67% of the control level of zinc and copper with 85% of the control level of manganese.

Table 1. Dietary treatments reducing trace mineral salts and replacing them with chelated trace minerals

Trace mineral	Control addition (ppm)	MMHAC addition (ppm)
Zn	75 (85% as zinc sulphate, 15% organic)	50
Cu	15 (85% as copper sulphate, 15% organic)	10
Mn	70 (83% as manganese oxide, 17% organic)	60

Egg weight, feed consumption, water consumption and feed conversion were not different between groups. MMHAC fed breeders tended to have a lower mortality than the control fed group with 0.8% fewer hens and 2.34% fewer roosters. There was also a greater number of eggs hatched in the MMHAC fed group. When studying egg quality, MMHAC fed hens tended to produce eggs with a more stable albumin height, which is a measure of 'freshness' and yolk pH, both of which are supported by greater oxidative balance.

There was a significant effect on hatched eggs and embryonic mortality between treatment groups. MMHAC fed hens produced eggs with significantly lower ($P < 0.05$) embryonic mortality at 27 weeks when store for 16 days and at 45 weeks when embryonic mortality ws significantly higher after both 7 and 14 days of storage as in Table 2.

Table 2. Embryonic mortality in fertile eggs sourced from hens fed higher inorganic versus lower chelated forms of trace minerals

	Parent stock age/storage duration (days)			
	27 weeks		45 weeks	
Embryonic mortality	9 days	16 days	7 days	14 days
Control egg abnormality	138a	218a	89a	149a
MMHAC egg abnormality	121a	151b	86b	96b
P value	>0.05	<0.05	<0.05	<0.05

This study demonstrated that the reduction of key trace minerals in breeding hen and rooster diets can be accomplished without reduction in hatched egg performance if they are replaced by highly bioavailable chelated minerals. This strategy will support the reduction in total trace minerals excreted and subsequent contamination of food crops. The reduction in embryonic mortality could be attributed to greater oxidative balance in the eggs, which was partially established by albumin height stability and stability in egg yolk pH. A greater understanding of the mechanisms supporting embryo survival should be pursued in future studies.

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Observation of Merino ewe body condition score on lamb live weight and survival to weaning

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Body condition score (BCS) of the pregnant ewe is a critical factor influencing peri- and post-partum lamb viability, growth and survival (Hinch and Brien 2014; Kenyon *et al.* 2014). It is widely accepted that maintaining twin-bearing ewes with a BCS of 3.0-3.3 during late gestation is the optimal range to maximise lamb development and reduce mortality (Kleemann and Walker 2005). The objective of this study was to determine whether the BCS of 96 twin-bearing, mature (3–7 years old) Merino ewes at approximately d123 of gestation would influence live weight (LW) and survival of their lambs from birth to weaning. We hypothesised that ewes with a BCS of ≤2.5 during late gestation would rear lighter lambs, with fewer of these lambs surviving to weaning. On d90, ewes received a commercial basal ewe and lamb pellet (DM at 89%; metabolisable energy: 12.7 MJ/kg, Laucke Mills, Daveyston, SA) via lick feeders as part of a large-scale twin lamb survival project. Ewe BCS was scored on d123 of gestation by a single operator. Lamb LW and survival was recorded at birth, marking (35.1 ± 0.4 days of age) and weaning (100.0 ± 0.4 days of age). The effects of ewe BCS on lamb survival at all time points was determined using a chi-square test and an ANOVA was conducted to determine the impact of BCS on lamb LW. Due to low numbers of ewes with a BCS of 2, these animals were combined with ewes scoring a BCS of 2.5 to create a BCS group of ≤2.5. Similarly, ewes with a BCS of 4 and above were grouped to create BCS ≥4. Ewe BCS group had no effect on lamb LW at birth ($P = 0.322$). At marking, lambs born to ewes in the BCS ≤2.5 group tended to be lighter than lambs born to BCS 3 and 3.5 ewes ($P = 0.071$). However, at weaning, lambs born to BCS ≤2.5 ewes were lighter than lambs born to BCS 3 and 3.5 group ewes ($P = 0.044$; Table 1). Cumulative survival rates of twin lambs were unaffected by ewe BCS group at all time points (each $P > 0.05$; Table 1).

Table 2: Mean live weight (LW) and percentage of the cumulative survival at birth, marking and weaning of lambs born to ewes with a body condition score (BCS) of ≤2.5, 3, 3.5 and ≥4 on d123 of gestation

Measure	Ewe BCS				
	≤2.5	3	3.5	≥4	*P*-value
n	18	124	34	12	
Lamb LW (kg)[A]					
Birth	4.74 ± 0.25	5.23 ± 0.10	5.00 ± 0.17	5.12 ± 0.34	0.322
Marking	12.14 ± 1.08	14.82 ± 0.48	15.25 ± 0.71	12.63 ± 1.32	0.071
Weaning	22.58 ± 1.46 [a]	27.22 ± 0.68 [b]	27.30 ± 0.97 [b]	26.22 ± 1.79 [ab]	0.044
Survival, % (*n*)					
Birth	100.0 (18)	95.2 (118)	100.0 (34)	91.7 (11)	0.369
Marking	83.3 (15)	78.2 (97)	94.1 (32)	83.3 (10)	0.204
Weaning	77.8 (14)	75.8 (94)	88.2 (30)	83.3 (10)	0.453

[A]Data are presented as estimated marginal means ± SEM. Superscripts indicate differences ($P < 0.05$) within row.

This study demonstrated that twin-bearing ewes with a BCS of 2.5 or less reared lighter lambs at weaning than BCS 3 and 3.5 group ewes. Ewe BCS and fat levels are positively related to milk production (Gibb and Treacher 1982). It is, therefore, suggested that ewes with a BCS of 2.5 or lower had less body fat to mobilise which may have negatively impacted their lactation performance and consequently the growth of their offspring. As such, it is not surprising that they weaned lighter lambs; however, it is interesting that this did not impact lamb survival from birth to weaning. In conclusion, these findings indicate that farmers should ensure that twin-bearing ewes maintain a BCS of above 2.5 during late gestation in order to maximise lamb growth and safeguard survival to weaning. The conclusions from this study provide further evidence of the importance of adequate ewe BCS for Australian Merino enterprises.

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Genetics of heifer puberty and growth in tropically adapted beef breeds

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Heifer reproductive performance is a driving factor for profitability in northern beef systems. Age at puberty (AP) directly influences conception rates and is a highly heritable early-in-life trait for the genetic improvement of female reproduction (Johnston *et al.* 2009). The research showed selection could occur with few major antagonisms with production traits. Recognising the relationship between AP and growth traits during sire selection has the potential to achieve desirable mating weights of pubertal heifers. The aim of this paper was to investigate the genetic relationship between age at puberty, weight at puberty (WP), and 600-day weight (600 dW) through use of sire EBVs.

As part of the 'Repronomics' project (Johnston *et al.* 2017) heifers (N = 2438) were weighed and ovarian scanned every 4–6 weeks to identify the age (AP) and weight (WP) at first-observed corpus luteum (CL). Heifer weight was also recorded when the heifer cohort was approximately 600 days of age (600 dW). The heifers were located at DAF Brian Pastures (Gayndah) and Spyglass (Charters Towers) Research Facilities from 2014 to 2020. The breeds recorded included Brahman, Droughtmaster and Santa Gertrudis. Each trait was analysed separately to estimate genetic parameters and estimated breeding values (EBV) using ASReml (Gilmour *et al.* 2009) and models included fixed effects associated with the experimental design. EBVs for sires (N = 91) with greater than 10 daughters recorded were plotted below.

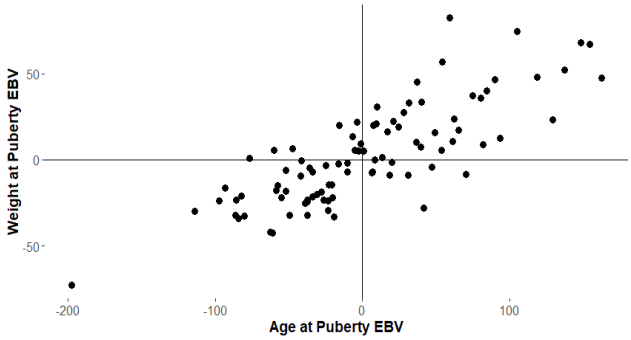

Fig. 1. Relationship between sire EBVs for age and weight at puberty.

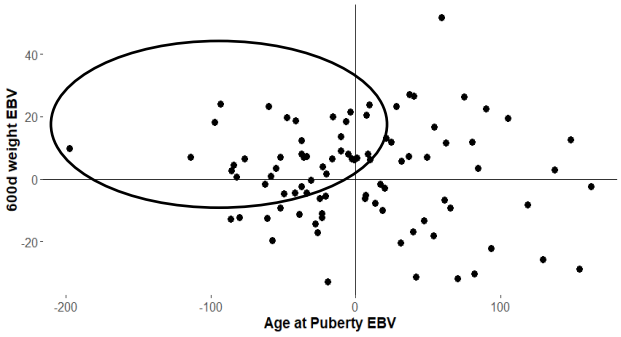

Fig. 2. Relationship between sire EBVs for age at puberty and 600d weight EBVs.

Fig. 1 displays a strong positive relationship between the sire's EBV showing that as age at puberty EBV increases, so does the EBV for the weight of the heifer at puberty. This indicates that those sires with daughters that were older at puberty were also likely to have heifers that were heavier at puberty. Conversely, younger age at puberty would be associated with lighter pubertal weight. However, Fig. 2 shows there was no observed relationship between 600 dW EBV and AP EBV and identifies sires (in the circle) that have early age at puberty as well as above average 600 dW. Further analyses could confirm these relationships through the estimation of genetic correlations between the traits allowing for development of multi-trait evaluations. The study could be expanded to estimate the relationship with other traits such as heifer fatness and body condition.

This study has shown it would be possible to select sires with EBVs for early age at puberty and heavier weights at mating, and therefore we expect a larger proportion of heifers that reach target into mating weights will also be pubertal. This will accelerate reproductive genetic improvement within the herd, resulting in increased conception rates, fewer instances of lighter pubertal heifers conceiving with associated risk of calving difficulties, and ensure above average growth genetics when selecting for early age at puberty.

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Performance of steers grazing Wondergraze or Redlands leucaena cultivars

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Leucaena (*Leucaena leucocephala*) is a leguminous shrub adapted to higher rainfall (>600 mm), frost-free areas of Australia. Leucaena leaves are high in crude protein (CP) and can increase animal performance when established in grass pastures. However, many cultivars are susceptible to attack from psyllids that can denude the plant of leaves. The psyllid resistant cultivar, Redlands, was commercially released in 2019. The objective of this study was to compare the leucaena edible yield and animal performance of steers grazing either Redlands or Wondergraze (another recent cultivar) in grass/leucaena pastures.

The study (approved under CSIRO Queensland Animal ethics committee (AEC2020-06) was conducted in 2021 in two established leucaena/grass pastures, each approximately 6.5 ha and divided into two replicates. Leucaena, either Wondergraze or Redlands, was established in 2017 in double rows each 12 m apart and accounted for 6% of paddock area. Six Droughtmaster steers were introduced to each replicate on 28 January 2021 and grazed continuously for 166 d. All cattle were dosed with a rumen inoculant of *Synergistes jonesii* specifically cultured for the appropriate cultivar. Cattle were weighed every two to four weeks and pasture and leucaena biomass (Tothill *et al*. 1992, modified for leucaena) and nutritive value (Near infra-red (NIR) analysis of forages and faeces) were measured on four occasions (February, March, June (not faeces) and July). For brevity, only data in February and July are reported here, however statistical analyses presented include all sampling times.

Leucaena edible biomass at turn-out was over 4 t/ha leucaena but declined quickly in response to grazing pressure (Table 1). Overall, there was no cultivar effect (P = 0.39) although biomass declined more rapidly in Redlands than Wondergraze (data not shown). When edible leucaena biomass was expressed per ha of the grazing area, it was apparent that biomass of leucaena in Redlands declined faster than in Wondergraze, such that, overall there was a significantly lower biomass in Redlands that Wondergraze (P = 0.02). Pasture biomass increased between February and July and was significantly higher for the Wondergraze paddocks (P = 0.04). Animal performance was not significantly different between cultivars but declined over time. Average LW gain over the grazing period was 0.78 and 0.81 kg/d (P = 0.86) for cattle grazing Redlands and Wondergraze, respectively. Faecal NIR measures of dietary N and faecal N and rumen ammonia N declined over the grazing period but there were no cultivar effects (Table 1).

Table 1. Animal performance, biomass and N dynamics of cattle fed leucaena throughout the grazing season

	Redlands		Wondergraze		S.E.	*P*-value	
	Feb	July	Feb	July		cv	Date
LW gain (kg/d)	1.42	0.39	1.48	0.45	0.27	0.86	<0.001
Pasture biomass (t DM/ha)	2.44	6.15	2.93	5.50	0.39	0.04	<0.001
Edible leucaena biomass							
t DM/ha established leucaena	5.20	0.14	4.31	0.22	0.32	0.39	<0.001
kg DM/ha grazing area	266	6.95	258	14.5	19.9	0.02	<0.001
Diet N (% DM)	2.45	1.46	2.60	1.42	0.06	0.16	<0.001
Faecal N (% DM)	2.52	1.57	2.65	1.50	0.06	0.65	<0.001
Rumen ammonia N (mg/dL)	15.8	5.29	19.4	6.13	1.06	0.20	<0.001

The study demonstrated that including leucaena in grass paddocks can result in high rates of LW gain. However, it is also apparent that the optimum balance between pasture and leucaena in the paddock is essential to sustain high rates of gain. The rapid decline in leucaena biomass suggested cattle were selecting leucaena. The biomass data suggested that selection for Redlands may have been greater than for Wondergraze. The high N indices in the diet, faeces and rumen are indicative of very high diet quality early in the grazing period, with diet CP being almost 16%. This blended CP intake estimated by faecal NIR, suggested that leucaena would have to compromise over 60% of the diet. By the end of the grazing period the CP content of the diet was below 10% for both treatments. These changes in diet quality were reflected in steer LW gain.

From indirect evidence (changes in leucaena and pasture biomass) there was some indication that cattle preferred Redlands over Wondergraze. However, this increase in grazing pressure resulted in a more rapid decline in Redlands edible biomass and presumably intake. Thus overall, both cultivars sustained similar levels of performance over the almost 6-month continuous grazing period. The data support the view that for maximum productivity, leucaena should be grazed in rotation to ensure adequate leucaena is available for sustained high rates of growth. These data suggest edible leucaena biomass should comprise approximately 10% of total pasture biomass.

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Tools for mitigating methane – modelling the value of genetics

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Ruminants contribute up to 80% of greenhouse gas (GHG) emissions from the livestock sector, and enteric methane production by ruminants, such as cattle, is the main source of these GHG emissions. Hence, reducing enteric methane production is essential in any GHG emissions reduction strategy in cattle. A number of strategies have been proposed to reduce methane production from ruminants. These fall into two broad classes: (1) non-genetic approaches, and (2) genetic improvement. Non-genetic approaches have centred on using feed additives, utilising improved pasture species or manipulating the microbiota of the rumen to reduce methane outputs (Black *et al*. 2021). The advantages of these activities are that they may be implemented for proposed immediate reduction in methane emissions. Their major disadvantages are that delivery is likely to be challenging in many production systems and they impose a continuous cost to the system. Genetic improvement focuses on selection of breeding animals that naturally emit lower methane amounts. The advantages of genetic approaches are that reductions in GHG emissions are cumulative and long-lasting across many years of production. However, the main disadvantage is that the proposed reduction is small per year. Previous studies have suggested that average emissions may be reduced by c. 0.5–2.5% pa (Barwick *et al.* 2019, Fennessy *et al.* 2018), however, few have modelled the long term, and cumulative impact selection may have on total GHG emissions from beef cattle. The aim of this study was to illustrate the potential reduction in methane emissions using genetic tools.

To model the impact of genetic selection for methane over time, a population of breeding cows of approximately 25 million (M) head that contributes ~35 mega tonnes (MT) of carbon dioxide equivalents (CO2e) per year was assumed. The amount of genetic change that was assumed was 1% per year, which was equivalent to a carbon price of $20 per tonne (Barwick *et al.* 2019). A development phase of 4 years was used represent development of estimated breeding values required to select animals based on methane production. The total cumulative reduction was estimated for 80% or 50% adoption of improved genetics.

Table 1 illustrates the impact of genetic selection resulting from a conservative estimate of 1% genetic gain per year and 50% and 80% adoption by beef cattle breeders.

Table 1. Predicted reduction in GHG emissions in MT CO2e by breeding more efficient beef cattle

Year	% reduction vs 2021		MT CO2e reduction per annum vs 2021		Total emissions from Australia's Beef Cattle herd (MT CO2e)	
Adoption rate	80%	50%	80%	50%	80%	50%
2021	0	0	0	0	34.9	34.9
2030	5	3	1.6	1	33.3	33.9
2035	8	5	2.9	1.8	32	33.1
2040	12	7	4.1	2.6	30.8	32.3

Using genetic selection for improved animals resulted in 7–12% reduction in methane outputs after 20 years. At a carbon price of $20/t this would represent a potential value of $50–$85M. Further to the predicted reductions it is important to note that Barwick *et al.* (2019) illustrated that if the costs of GHG emissions are ignored, GHG emissions will substantially increase over time (e.g. ~1% per year under current beef cattle breeding objectives). This is equivalent to an increase of ~5 MT of CO2e in 20 years. Therefore, the total predicted gain is equal to ~9 MT of CO2e net benefit by including an objective of methane reduction in the breeding program.

The reduction in methane due to genetic change assumes only a small amount of selection pressure against emissions. This reduction could be achieved at very modest cost, based on collecting phenotypic data in the reference populations of the main breeds. At the same time, the reduction based on genetics also reduces the population-wide cost of non-genetic approaches. More intense selection against emissions, reflecting a higher price for carbon, could deliver much larger genetic reductions, 2.5% pa with minimal loss of genetic progress in other traits is feasible (Barwick *et al.* 2019), with the simultaneous reduction in cost of non-genetic approaches.

Very large and rapid reductions in emissions from ruminants seems likely to be expensive, reflecting relatively limited methods available to date and potentially high demand. Genetic solutions provide a long-term tool for the reduction of methane output but also as a tool to reduce the costs that are likely to be incurred by other methods of methane mitigation. In the long term more modelling of a realistic scenario of combined use of genetic and non-genetic tools is required to better understand the implications, costs and value of varying mitigation tools.

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Dietary 1α-hydroxyvitamin D3 increases the concentration of phosphorus in the plasma of ewes

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Vitamin D metabolites provide a novel method to increase the efficiency of bodily phosphorus (P) and calcium (Ca) use by increasing absorption and retention along with inducing bone remodelling and deposition. These compounds may have potential application for livestock where P demand is high and in grazing environments that are deficient in P. The non-endogenous compound 1α-hydroxyvitamin D3 (1(OH)D3) utilised in the treatment of human osteoporosis bypasses the tightly regulated step of 1α-hydroxylase in the kidney to create the active hormone form of the vitamin, 1,25α-dihydroxyvitamin D3. The few available ruminant studies have shown that it has a positive effect on blood P and Ca status but studies have been restricted to intramuscular injection over a relatively short period of time (Sachs *et al.* 1987; Naito *et al.* 1987; Braithwaite 1980). It was hypothesised that dietary 1(OH)D3 supplementation would have a positive and sustained effect on plasma phosphorus concentrations over an 84-day period, utilising sheep as a model ruminant.

The experiment was undertaken from 2 September to 29 November 2021. Twelve mature Merino ewes (Liveweight (LW) 50–55 kg) were blocked by weight and randomly assigned into two treatment groups of six ewes – control and 1(OH)D3. All sheep were individually fed a common basal pellet diet for the duration (Dry matter basis: Intake 2% LW, 11.1MJ metabolisable energy/kg, 19.2% crude protein, 0.28% P, 0.30% Ca, with 1g/kg supplement premix incl. 250IU Vitamin D3 per day). The 1(OH)D3 group had this diet supplemented, based on human dietary interventions, with 2µg of 1(OH)D3 (Glentham Life Sciences, UK) applied as 2mL of 1µg 1(OH)D3/mL (made daily in Milli-Q water) mixed with 200g basal diet provided before feeding the rest of the daily ration. Sheep were weighed and plasma samples were collected on days 0, 14, 28, 46, 56, 70 and 84. Plasma concentrations of P were measured using an Indiko Plus auto-analyser (ThermoFisher, Vantaa, Finland). Data analysis was by one-way ANOVA at each time point, using RStudio, with significance tested at $P < 0.05$.

Plasma P increased ($P < 0.05$) in the 1(OH)D3 group by an average of 44% (Range: 34.5–57.7%) compared to the control from day 28 onwards (Fig. 1), but no effect on LW was detected (data not presented). Between days 28–84, the mean P levels of the 1(OH)D3 group were consistently higher than reference plasma P values in sheep (1.62–2.36 mmol/L; Kaneko *et al*. 2008).

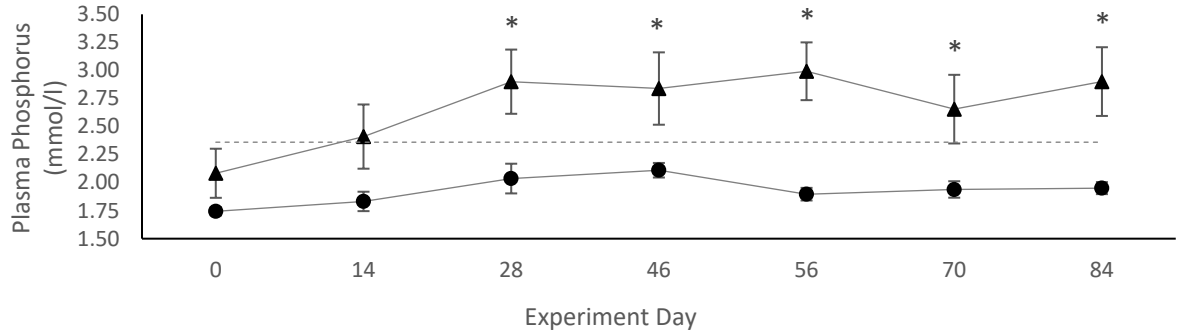

Fig. 1. Plasma P levels in Merino ewes in Control (●) and 1(OH)D3 (▲) groups during the experiment. Error bars are standard error of the mean, and an asterisk (*) above a point shows a significant ($P < 0.05$) result compared to the control group. Dotted line represents higher limit of reference plasma P levels in sheep (2.36 mmol/L) as described in Kaneko *et al.* (2008).

This is the first trial of its kind investigating supplementation of dietary 1(OH)D3, as well as its long-term effects on plasma P levels in ruminants. Dosage rates of 2µg/day (0.04µg/kg LW) show a positive, sustained increase in plasma P from 28 days, and suggests a potential for the use of 1(OH)D3 to increase bone P reserves, enabling animals to utilise these bodily reserves as a form of self-supplementation when needed. As such, but with further development of dosage to ensure metabolic safety, 1(OH)D3 shows potential to be a potent and economically viable supplement. Further analysis of samples from this trial will elucidate the effects of the treatment on bone physiology and deposition.

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Measuring milk yield of tropically-adapted cows from neonatal calf growth

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Beef cattle in dry tropical regions experience high calf mortality rates (Fordyce *et al.* 2021). A major risk factor appears to be low milk production and delivery during the first week after birth, the highest-risk period for calf mortality (Muller *et al.* 2020). Monitoring milk production in tropically adapted *Bos indicus* cows in the field is difficult, and so we sought to validate a practical and cheap method to measure milk yield in *Bos indicus* cows that can be applied in the field.

Twenty-four newborn Brahman calves were removed from their dams 3 days after birth to ensure adequate colostrum intake. Vigorous nursing was observed in all 24 calves. Each calf was randomly allocated to one of four treatments: 2.3 kg/d, 3.5 kg/d, 5.5 kg/d, or 7.5 kg/d of fresh Holstein milk collected from late lactation cows. The first 12 newborn calves were randomly allocated to one of four treatments on birth date and the remaining 12 newborn calves were allocated on sex to balance the group. The treatments were based on the calculated metabolisable energy requirements for a 35 kg dairy calf to attain an average daily gain (ADG) of 50 g/d, 400 g/d, 800 g/d, or 1200 g/d, respectively (NRC 2001). Calves were weighed three times per week for two weeks and ADG was calculated by regression. Total intake was adjusted based on analysed Holstein milk composition and estimated Brahman's milk composition. It was assumed that whole milk from Brahman cows contains approximately 5.7% fat, 3.2% protein, and 5.0% lactose (Daley *et al.* 1987). The relationship between Brahman adjusted milk intake and ADG was tested using linear regression analysis.

Average birth weight was 32.1 ± 5.8 kg and weight at 14 days was 38.1 ± 9.3 kg. There was a strong linear relationship between milk intake and calf ADG kg/d = 0.208 x Milk intake (kg) – 0.403; RMSE = 0.11; R^2 = 0.89. Average calculated maintenance requirements for these neonatal calves was 1.94 kg milk/day. Predicted 14 d growth Brahman calves with different milk intakes (Fig.1) illustrates the potential impact on early growth.

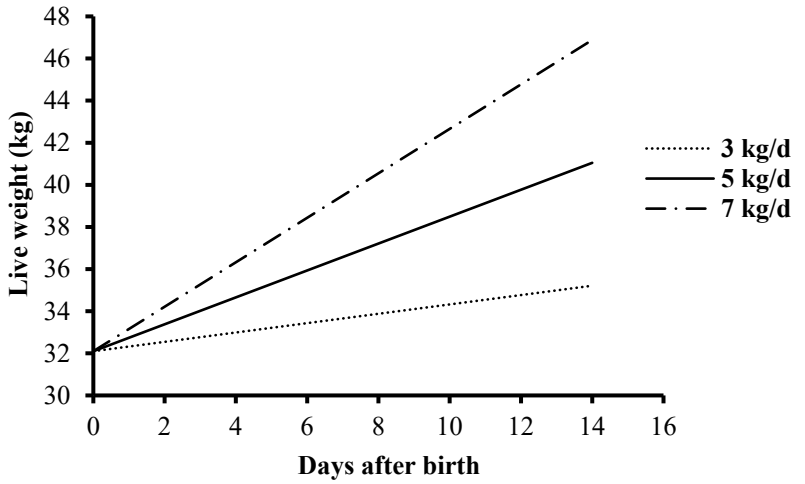

Fig. 1. Estimated live weight gain of Brahman calves (32.1 kg birth weight) receiving 3, 5, or 7 kg of milk per day.

It was concluded that on-farm, growth rates of *Bos indicus* calves in the first week of life can be used as an accurate method to monitor changes in milk delivery of dams. Knowledge of milk delivery changes in the field will enable beef cattle producers to better evaluate the benefits of management interventions, such as better nutrition of prepartum and early lactation cows, aiming to increase calf survival.

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Smallholder goat production systems in Lao PDR: assessing production efficiency

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Goat numbers in Lao PDR are increasing rapidly, fuelled by exports of goats to Vietnam. Since 2017 the Australian Centre for International Agricultural Research (ACIAR) has worked with government agencies in Lao PDR and Vietnam to evaluate the sustainability and future direction of this trade and the production systems underpinning it. Research to date has identified that almost all production in Lao PDR is by smallholders and was found to contribute 35 ± 16% of household income in goat keeping households (Gray *et al*. 2019). Smallholder systems, particularly in the lowlands, benefit from a relatively low-cost production model in which goats are typically housed at night and released to graze unsupervised on communal land during the day. Vulnerable crops, rather than livestock, are fenced and free ranging and browsing behaviour limits the severity of helminthiasis. Goats are sold to visiting traders at high prices, commanding a premium in Vietnam of 20–40% over local Vietnamese crossbred goats with farmers capturing approximately 70% of the market value of goats they sell (Gray *et al*. 2019).

This study is part of the 'Goat Production Systems and Marketing in Lao PDR and Vietnam Project (LS/2017/034)' funded by the Australian Government though ACIAR and was approved by University of New England Human Ethics Committee (HE19-218). The study is focused on smallholder goat farmers in seven villages in the central province of Savannakhet, Lao PDR. Ten households in each of 7 villages (n = 70 households) were registered to take part in a series of surveys of their goat production system including a monthly household survey (MHS). The results presented are from 16 months of MHS. Only households that completed three or more MHS were included in the analysis (n = 60). Researchers from the National Agriculture and Forestry Research Institute interviewed the farmers in Lao language using a survey built in CommCare® software (Dimagi Ltd, Cambridge, MA, USA). The survey included questions on household farming activities and changes in the goat herd (births, deaths, sales, purchases and lost goats). These data were used to calculate key production indicators including mean number of kids/doe/year, litter size, annual rate of sales (%), annual mortality rate (%), annual rate of goats going missing (%). To utilise the most complete dataset available the data collected over 15 months were annualised. The objective of this study was to assess production efficiency of smallholder goat farms in Lao PDR.

The mean goat number (including does, kids and bucks) over the 16-month period was 11.5 goats per household. The mean number of live kids/doe/year was 1.9 (Table 1). The rate of sales (total sales/mean monthly goat number) was highly variable with four farmers reporting zero sales and two reporting very high rates of sales. Kids comprised the majority of the annual mortality rate (total deaths/mean monthly goat number) and some households suffered a surprisingly high rate of missing goats (Table 1).

Table 1. Mean annual key production indicators of smallholder goat production systems in Lao PDR

	Number of kids/doe/year	Number of kids/litter	Annual rate of sales (%)	Annual total mortality rate (%)	Annual kid mortality rate (%)	Annual missing goat rate (%)
Mean	1.9	1.6	65.4%,	37.5%	26.3%,	7.9%
Median	1.8	1.5	56.3	30.0%	20.0%	0%
Range	0.2–3.9	1–3	0–327.4%	0–143.3%	0–84.7%	0–55.7%

This study found that smallholder goat production systems in central Lao PDR had good reproductive performance with the mean number of kids/doe/year being higher than those reported in other studies of goats in Laos (1.3 kids/doe/year; Kounnavongsa *et al.* 2010) and in high rainfall areas of Australia (1.6 kids/doe/year; Nogueira *et al.* 2016). Mean litter size was the same as reported by Kounnavongsa *et al.* (2010). The upper range of mortality rates and rates of sales are plausible for the upper range of kidding rates and/or with short term trading of goats. They may also reflect events where large numbers of goats were sold or died. These would have a small effect on average herd size but a very large effect on the number of goats sold or died. The high mortality rate is currently being investigated with disease causation studies. Through interventions including ensuring kids are born into a clean, dry, warm and ventilated goat house, and improving overall nutritional status, the project aims to reduce kid mortality to increase the annual rate of sales and profitability of goat raising for smallholders.

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Pasture legumes for high-quality dry-season cattle forage on red basalt soils in north Queensland

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Beef cattle production in the seasonally dry zone of north Queensland is based on uncleared native grasslands. Rainfall-related cycles in native grass growth and maturation results in low levels of dietary protein and metabolisable energy during the dry season (May-October in most years), which limits animal growth and business productivity (Rolfe *et al.* 2016). Sown legumes (notably *Stylosanthes* spp.) can improve the seasonal supply and quality of feed on infertile soils used for extensive grazing (Anon 1994) and is the best option to improve business resilience and profitability (Bowen *et al*. 2019). The Department of Agriculture and Fisheries is testing 'production paddocks' using pasture legumes grown in strips (as one option) and supplementing soil available phosphorous (P) and/or sulphur (S) to improve dry-season diets. Initially a range of pasture legumes were grown in replicated (3) small plots on 14 land-types to identify legume (and grass) lines for subsequent research. The results presented here represent red basalt soils near Mt. Surprise in north Queensland, characterised by high available soil P and low S. This land-type can produce 2900 kg DM/ha native grass in good condition (Ash *et al*. 2016), but is often degraded and invaded by low biomass grasses (e.g. *Bothriochloa pertusa*).

Twenty-nine legumes (14 taxa groups) were sown in rows into a cultivated site in 2014 (tines and glyphosate). Fertiliser S (24 kg/ha) was applied pre-plant only. After the establishment year, the plots were 're-set' each season by cutting (10 cm) after a 'green date' (50 mm rainfall over 4 weeks) and grown without grazing until the season was considered finished (no forecast rainfall). Herbage yield was measured (two 0.3 m^2 quadrats per plot; drying at 70°C until constant weight) and separated into leaf (leaves and fine material (< 2 mm stems) or stems). The plots were then grazed to a residual of ~1500 kg DM/ha. Sub-samples of leaf and stem grown for similar periods, but sampled in subsequent years, were analysed for feed value using wet chemistry procedures (Dairy One™).

Herbage yields are presented for years two and three after the establishment year (when effects due to cultivation are likely to have subsided) (Table 1). Other legume species (*Centrosema spp., Macroptilium gracile*) did not persist beyond the first year despite establishing well (data not presented). Some legumes produced high total herbage yields (notably *Stylosanthes seabrana* and *S. scabra*) but a large proportion of this was stem. Yields were highest in year 2, which had the longest growing period and highest rainfall component. Of the most persistent legumes, *C. ternatea, S. seabrana* and *S. scabra* produced the most leaf (<2.5 T DM/ha). High quality feed was produced in the dry season. The feed value of the legume leaf was high (~14-21% crude protein (CP); 8.2-9.5 MJ/kg metabolisable energy (ME)) for all legumes but lower for stem particularly for the erect shrubby types with thicker stems (*Desmanthus, S. scabra, S. seabrana*). Feed quality (crude protein and metabolisable energy) of plants sampled 15 weeks after the onset of the growing season was higher than for samples collected after 26 weeks.

Table 1. Mean herbage yields[A] and feed quality of legumes grown on a red basalt soil (kraznozem) in north Qld, sampled during the early and mid- dry season[B] and separated into leaf and stem components. The plots were sown on 4 March 2014

	Herbage yield (T DM/ha)								Crude protein (% wt DM)				Metabolisable Energy (MJ/kg)			
	28 months after sowing				38 months after sowing											
	27 weeks growth* (875 mm) 26 June 2016				16 weeks growth* (521 mm) 27 April 2017				15 weeks growth* (469 mm) 6 May 2020		26 weeks growth* (651 mm) 13 June 2018		15 weeks growth* (469 mm) 6 May 2020		26 weeks growth* (651 mm) 13 June 2018	
	Leaf		Stem		Leaf		Stem		Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Clitoria ternatea	1.93	*0.42*	2.71	*1.20*	2.65	*0.62*	1.46	*0.27*	20.8	10.4	17.8	6.6	8.9	5.4	8.4	5.0
Desmanthus spp.	1.09	*0.19*	2.45	*0.29*	0.66	*0.11*	1.36	*0.18*	15.0	5.7	13.8	6.1	9.5	5.6	8.2	6.3
Macroptilium atropurpureum	1.02	*0.26*	1.26	*0.21*	-		-		15.2	9.4			8.3	6.6		
M. bracteatum	0.48	*0.18*	1.19	*0.59*	-		-				14.2	5.5			9.5	5.9
Stylosanthes guianensis	1.63	*0.29*	2.22	*0.41*	0.64	*0.14*	0.81	*0.17*	15.0	8.8			8.7	5.8		
S. hamata	0.55	*0.17*	0.94	*0.37*	-		-		17.4	9.7			9.3	7.1		
S. scabra	2.88	*0.73*	5.70	*1.46*	1.45	*0.27*	2.01	*0.39*	17.6	7.2	14.3	6.7	8.2	4.9	9.3	5.3
S. seabrana	2.40	*0.35*	8.45	*1.58*	2.61	*0.30*	6.01	*0.71*	18.0	7.9	16.4	5.9	8.9	5.6	9.0	5.6

[A]Standard errors of herbage yield means are represented in italics.
[B]The growing period is denoted with * and represents since green date (50 mm rainfall within 4 weeks).

The use of legume strips sown into native grasslands has potential to significantly increase the volume and quality of feed during the early- to mid- dry season on red basalt soils in north Queensland and warrants testing on a semi-commercial scale. Research should target maximising the amount of legume leaf produced during the dry season through testing grazing management strategies and measuring animal performance and pasture productivity and stability.

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Efficacy of zeolite in reducing NH_3 production in beef cattle manure in an *in vitro* system

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Ammonia (NH_3) emissions from manure can contribute to negative welfare outcomes for both humans and animals in livestock industries, and techniques to limit NH_3 volatilisation from the manure pad are being researched (McCrory and Hobbs 2001). Zeolite is a naturally occurring aluminosilicate present in sedimentary rock, compositionally similar to clay minerals but characterised by a unique three-dimensional structure and high cation exchange capacity that can selectively retain ammonium (NH_4^+) ions (Ramesh and Reddy 2011). The current recommended application rates are highly variable, depending on industry application and particle diameter, and there is opportunity to investigate the capacity for adsorption of ambient NH_3 from the air. This experiment aimed to determine the most effective zeolite application rate for reduction of NH_3 volatilisation from the cattle manure pad, and to test ambient application of zeolite, *in vitro*.

The *in vitro* apparatus utilised: 12 PVC microchambers of identical size (90 mm diameter x 150 mm height), with an air inlet and outlet; acid traps consisting of 250 mL measuring cylinders with volumetric tops and rubber stoppers containing 200 mL of 2% (0.32 mol/L) boric acid (through which the exhaust air from the microchambers was bubbled); and a small multiplexer system of pumps (2 L/min capacity). Total fresh urine and faeces was collected over a 24 h period from three individually penned Angus steers fed a maintenance diet (9–12% CP, ME >8.0 MJ/kgDM) at 2% bodyweight in an indoor shed environment (UNE animal ethics approval number ARA171-200). Manure was mechanically homogenised and 30mm weighed into each of 12 microchambers. Zeolite of 2–4 mm particle size was applied, in duplicate, at rates of 1, 3, 5 and 10% of manure weight, with a fifth treatment containing the equivalent to 5% zeolite suspended from the interior surface of the vessel lid. The microchambers were incubated at 25°C for 21 h. Air exhaust flow rates of 0.5 L/min were calculated relative to microchamber air volume based on an air exchange (AE) rate of 42 AE/h. 0.5 mL samples were collected from the acid trap –15, 0 and +15 min from sampling times of 3 and 21 h incubation and stored at room temperature. The process was repeated for two further runs for a total of six replicates, using refrigerated manure warmed to approximately 25°C in a water bath prior to being loaded into the microchambers as per the previous run. Samples were assayed for NH_3-N using a colorimetric Berthelot assay (J. W. Clay, pers. comm., 2021).

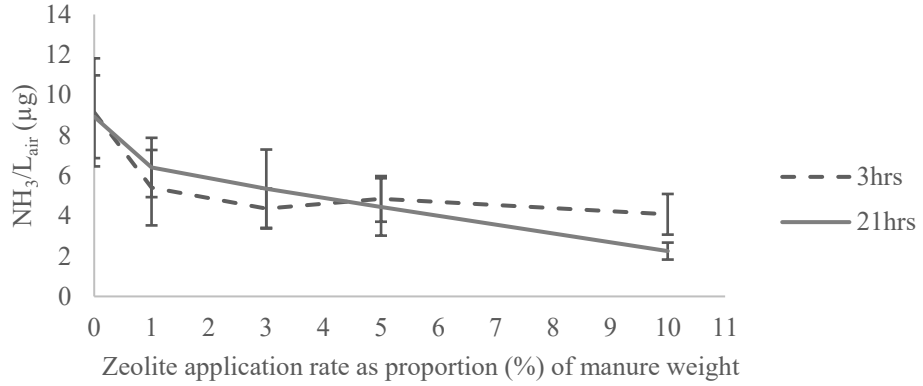

Fig. 1. Mean NH_3/L_{air} (µg) of in-pad zeolite treatments at 3 and 21 h of incubation**.** Values are mean of six replicates, with 0 being control treatment.

Both the 3 and 21 h values show a linear relationship between increasing zeolite application rate and decrease in mean NH_3/L_{air} (µg) (r^2 = 0.464 and 0.8915 respectively) (Fig. 1). Proportion reduction for in-pad applications ranged from a mean of 36.80% (±19.83) to 48.62% (±9.30%) at 3 h, and 27.98% (±6.25%) to 71.71% (±4.20%) at 21 h compared to control. Outcomes for the ambient zeolite application show potential for further investigation with a reduction of 9.70% (±17.26%) and 29.80% (±5.94%) at 3 and 21 h respectively. With 1% zeolite application yielding a minimum 27.98% (±6.25%) reduction, there is promise for zeolite to provide an economical solution to reducing the impact of NH_3 in industry conditions where cattle are intensively housed.

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Investigating the cause and prevention of red gut in lambs grazing lucerne

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Red gut is an enteric disease of sheep that occurs on high protein low fibre diets, predisposing to gastrointestinal instability (Gumbrell 1997). Volvulus of the intestinal mass may follow leading to an intensely red coloured obstruction, shock, and sudden death (Jagusch *et al.* 1976). Fibre supplementation and rotational grazing are the only current recommended preventative strategies (Jagusch *et al.* 1977). The highest risk is for lambs grazing lucerne, particularly monocultures grown for seed production (Jagusch *et al.* 1976). Red gut prevalence has been reported at up to 10% in lambs in the upper south east of South Australia. This study aimed to identify any significant associations between farming practices and the prevalence of red gut as well as recording the impact of a calcium-based foliar spray on disease prevalence. It was hypothesised that farm management factors would be found that influence the prevalence of red gut in lambs grazing lucerne. It has also been postulated that nutrient deficiencies, especially calcium, associated with the characteristic sandy soils in this area predispose to red gut through reduced plant fibre content (Mintz *et al.* 2021).

The study concentrated on lucerne seed producers that were in the upper south east of South Australia. A total of 27 producers participated in a survey to collect information regarding their farm management practice, particularly concerning lambs grazed on lucerne pastures. Study participants were asked to promptly report lamb deaths that occurred while grazing on lucerne in July and August 2021so that a post mortem could be conducted within 48 hours of death. A calcium-based foliar was also applied to selected grazed paddocks and compared to paired untreated grazed paddocks to see if this influenced red gut prevalence. Plant mineral content and feed quality of the treated and untreated paddocks were also monitored. All data was entered into Excel and imported for analysis in SPSS, using frequencies and a series of multiple linear regression analyses using the MIXED procedure.

A total of 17 deaths were investigated: 71% (n = 12) were diagnosed as due to enterotoxaemia, 24% (n = 4) red gut, and 6% (n = 1) ruminal acidosis. Insufficient sample size prevented statistical investigation of associations between red gut and farming practices. Over 40% of participating producers reported no lamb deaths during the trial period and approximately 50% reported a below average death risk for the winter period. No differences were found in the nutrient analyses between the treated and untreated paddocks. All trial paddocks recorded high levels of crude protein and metabolisable energy, coinciding with lower fibre content and were considered high risk pastures for grazing sheep.

Low sample size and mortality rate were the main limitations to the investigation. It was concluded that red gut was less prevalent in this study compared to previous reports, likely due to a range of factors including previous misdiagnosis, seasonal differences, and modified management practices. Producers appear to have reduced the occurrence of red gut through improved feed supplementation and grazing management strategies. Further studies on these farm management practices including the use of foliar sprays would help to elucidate red gut prevention strategies.

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The probiotic Bovacillus™ fed in a lick increased liveweight gain of yearling heifers

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Bovacillus™ is a feed stable probiotic produced by Chr Hansen, Denmark containing *Bacillus* species. Recently, Pan *et al.* (2021) showed Bovacillus™ enhanced fibre digestion for 9 out of 10 forages tested. These results are consistent with those of another *in vitro* study in Brazil (Oliveira *et al.* 2016) where these same bacteria gave a cubical increase in the neutral detergent fibre digestibility of forages. Based on these results, a pilot study was conducted to test the hypothesis that feeding Bovacillus™ would increase the liveweight gain of yearling heifers grazing a low-quality pasture in northern Australia.

Three hundred 12–18-month-old Brahman and Brahman cross heifers were individually weighed (Ruddweigh scales) and alternately tagged into two random groups of green and yellow tags. The study was conducted using an 800 ha paddock at Glenmore Station in North Queensland. The paddock was open forest, granite country consisting mainly of seca stylo with black and white speargrass and had been subdivided into two paddocks, with water supplied directly by a dam in one and a trough with water from the dam in the other. Yellow tagged heifers went into the paddock with the dam, and green tag heifers went into the paddock with the trough. Two weeks after the heifers were allocated to the paddocks, faecal samples were collected from each group and submitted to Symbio Laboratories, Brisbane, Queensland. Near-infrared reflectance spectroscopy analysis of the faeces was used to determine dry matter digestibility of the pasture selected by each group to estimate metabolisable energy (ME) expressed as MJ ME/100 kg liveweight. The faeces from the green tagged heifers gave a diet ME of 11.7 MJ/100 kg liveweight while the faeces from the yellow tagged heifers gave a diet ME of 11.1 MJ/100 kg liveweight. Although both ME values were too low to maintain the heifers (MAFF 1975), to help minimise possible paddock bias and any advantage to the Bovacillus™ group, the yellow tagged heifers were allocated to the Bovacillus™ group and the green tagged heifers were allocated to the control group. Due to the logistics of weighing the heifers and faecal sampling, lick was not offered until 32 days after initial weighing. The urea-based, loose lick formulation provided *ad libitum* contained; 24% soyabean meal, 21.65% salt, 15% mono-dicalcium phosphate, 15% urea, 12.7% canola meal, 5% sulphate of ammonia, 2% elemental sulphur, 2% molasses, 2% stock lime, 0.2% trace mineral premix and 0.15% vitamin premix plus 0.3% of 10% active monensin sodium (Stocklick Trading, Charters Towers, Queensland). The lick had a minimum equivalent crude protein of 49.5% (12.1% true protein), 4.5 MJ ME/kg, 3.5% phosphorus, 3.3% calcium, 3.3% sulphur and 0.1% magnesium (as-fed basis). The Bovacillus™ group, also had 1.92 x 10^7 CFU/g of Bovacillus™ included in the lick. Over a 70-day period the control group consumed 190 g/head.day of the lick while the Bovacillus™ group consumed 238 g/head.day. After the final weighing, 9 animals were excluded from the data set – 4 missing, 2 steers, 1 had calved, 1 from an older age-group and 1 with the final liveweight recorded incorrectly. This resulted in the data set having 147 heifers in the Control group and 144 in the Bovacillus™ group. The data was analysed using a PROC MIXED model in SAS software, Version 9.4.

Table 1. Initial and final liveweight and liveweight gain (kg) per head for yearling heifers fed a dry-season lick for 70 days with and without Bovacillus™[A]

	Control group	SEM	Min	Max	Bovacillus™ group	SEM	Min	Max	*P*-value
Initial Liveweight (kg)	207.9	3.75	109	322	201.4	3.71	114	353	-
Final Liveweight (kg)	210.4	3.63	116	327	212.4	3.59	128	357	-
Liveweight Gain (kg)	2.5[a]	0.55	–21	22	11.0[b]	0.56	-6	32	<0.0001

[A]Values are means, standard error of the mean (SEM) with the *P*-value from the PROC MIXED model; row-wise superscripts indicate differences between means.

In support of our hypothesis, the heifers in the Bovacillus™ group gained an average of 8.5 kg liveweight compared to the control group (Table 1). In addition, 92% of the heifers in the Bovacillus™ group gained weight compared to 64% in the control group. Although the Bovacillus™ group ate more lick, the extra 48g/head.day consumed would account for only a small amount of the difference in liveweight gain between the two groups. It is difficult for ruminant animals to gain or even maintain liveweight on low-quality forages (McLennan *et al.* 2017). Furthermore, there are limited cost-effective alternatives for supplementary feeding of ruminants to enhance forage fibre digestion and/or intake to achieve sustainable production outcomes. Although this field study has limitations**,** the results indicate the consumption of Bovacillus™ may increase the liveweight gain of cattle consuming low-quality forages and warrant further research.

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Using plasma urea nitrogen to assess performance of steers on a low crude protein diet

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The production systems of northern Australia rely on low quality forage for much of the year. Nitrogen (N) availability limits cattle performance in these environments and it has been shown that there is individual variation in nitrogen use efficiency (NUE) on low protein diets (Carmona *et al.* 2020). This variation could be explained by variation in N recycling between animals (Silva *et al.* 2019). Differences in N recycling ability and urinary N losses can be reflected in plasma urea nitrogen (PUN) dynamics throughout the day. A small pilot study was conducted using a sub-set of cattle from a larger study to investigate whether those animals with divergent growth rates on low protein diets also had variation in PUN levels. It was hypothesised that cattle that perform better in terms of average daily gain (ADG) without supplementation can maintain higher PUN over 10 h.

This study was conducted at the Queensland Animal Science Precinct at Gatton, Qld, 4350 and was approved by the University of Queensland Animal Ethics committee. Twenty-four *Bos indicus* steers were fed a low-quality diet (approximately 6.3 % crude protein) for 9 weeks and then transitioned onto a molasses supplement with 8% urea offered at 10% of hay dry matter intake (DMI, approximately 8.1 % crude protein). After 9 weeks on the urea-supplemented diet catheters were inserted into the jugular vein and plasma samples taken at 0, 10, 20, 30, 60, 90, 120, 180, 240, 300, 360, 480, 600 min post-feeding in 8 steers. We selected 4 steers with low or negative ADG (–36 ± 32 g/d) and 4 with higher ADG (107 ± 17 g/d). The steers were selected based on their ADG in the non-supplemented portion of the trial. It is important to note that although we selected the steers based on their ADG on the non-supplemented diet the PUN was measured on the urea supplemented diet. There was no difference in ADG between the two groups of steers on the urea supplemented diet.

There was a significant difference in the ability of steers to maintain PUN levels (mmol/L) in steers that had higher ADG on poor quality hay compared to those with low or negative ADG (Fig. 1). There was an observed difference in urea elimination rate between the low ADG and high ADG animals, as indicated by the increase in the differences in PUN values after the peak at 4 h after feeding.

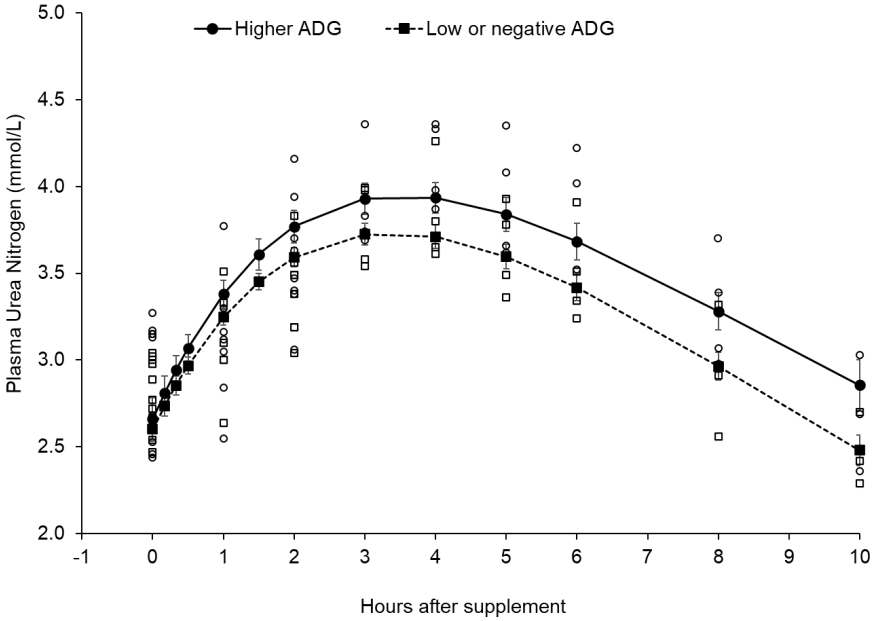

Fig. 1. Plasma urea nitrogen (PUN) in 8 steers classified into groups with low or negative (-36 ± 32 g/d) or higher (107 ± 17 g/d) average daily gain (ADG) on non-supplemented poor-quality hay (6.3% CP). Observed PUN values over a 10 h period are shown (low (□) and higher (o) ADG).

In conclusion, cattle that have higher ADG on poor quality diets maintained higher PUN levels after feeding with slower PUN disappearance rate. This may be due to an increased ability to recycle N through the hepatic system and back into the rumen where it can be used for rumen microbial protein synthesis instead of lost in the urine.

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Evaluating amino acid profiles and birth traits between single and twin Merino lambs

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Previous research has reported lower amino acid (AA) concentrations in twin fetuses at day 140 of gestation, compared to singletons (Van der Linden *et al.* 2013). Identifying variations in AA profiles is important to recognise nutritional deficiencies that may be affecting the developing fetus. This pilot study aimed to quantify the AA concentrations and blood gas values of a subset of twin and single lambs at birth, for use in subsequent research. This research contributes to the available information on baseline AA concentrations and blood gas profiles in merino neonatal lambs.

Blood samples were collected from 130 lambs immediately after birth, before consumption of colostrum. Blood gases were measured with an i-Stat Alinity point-of-care analyser and CG8+ cartridges (Abbott Point of Care, i-Stat Alinity, Abbott Park, IL, USA). A subset of plasma samples (10 single and 10 pairs of twins) was analysed for 19 free AA profiles by the Australian Proteome Analysis Facility, Macquarie University.

A general linear mixed model (SPSS ® 28, IBM) was used to evaluate the blood gases and AA concentrations (µg/mL) between singles and twins. Type of birth was included as a fixed effect. Sex was fitted in the model where significant ($P < 0.05$). Ewe identification number was fitted as a random effect to account for animals born to the same dam.

Birth type did not have a significant effect on blood gases measured, except for blood pH which showed a trend ($P < 0.10$). Averages for blood gases (single; twin or overall) were: pH (7.23; 7.21), partial pressure of carbon dioxide (62.56 mmHg), partial pressure of oxygen (24.80 mmHg), bicarbonate (26.10 mmol/L), base excess (–2 mmol/L), oxygen saturation (31.62 %), total carbon dioxide (27.49 mmol/L), sodium (146.67 mmol/L), potassium (4.8 mmol/L), ionised calcium (1.36 mmol/L), haematocrit (38 %) and haemoglobin (128.18 g/L).

Aspartic acid, isoleucine, leucine, and phenylalanine concentrations differed significantly between birth types (Table 1), but for alanine, asparagine and tyrosine it was only a trend ($P < 0.10$). There were no significant differences between singleton and twin lambs (overall mean) for arginine (12.05 µg/mL), glutamic acid (26.99 µg/mL), glutamine (73.88 µg/mL), glycine (72.09 µg/mL), histidine (11.43 µg/mL), lysine (11.93 µg/mL), methionine (4.62 g/mL), proline (28.69 µg/mL), serine (25.97 µg/mL), threonine (23.69 µg/mL), tryptophan (1.66 µg/mL) and valine (40.09 µg/mL).

Table 1. Mean plasma amino acid concentrations (µg/mL) for single and twin lambs at birth

	Singles (n = 10)	Twins (n = 10 pairs)	% Difference	P-value
Alanine	56.49±5.54	43.69±4.74	22.7	0.096ˆ
Aspartic acid	0.75±0.07	0.54±0.06	28.7	0.036*
Asparagine	9.50±1.03	6.76±0.97	28.9	0.068ˆ
Isoleucine	9.69±1.14	5.09±1.11	47.5	0.010*
Leucine	21.00±2.44	11.66±2.39	44.5	0.014*
Phenylalanine	12.82±0.85	9.79±0.82	23.7	0.019*
Tyrosine	16.49±1.17	13.71±1.09	16.9	0.098ˆ

Values are least-square means ± standard error of the mean (SEM) and P-values ($P < 0.05$). Values of statistical significance is indicated by * ($P < 0.05$). Statistical trends are indicated by ˆ ($P < 0.10$).

Twin lambs generally had lower AA concentrations than single lambs, which may be indicative of nutritional deficiencies during fetal development, while the blood gas results describe the impact of environmental effects on metabolism and short-term physiological responses to birth. The trend that is seen in pH is suggestive of mild acidosis, potentially caused by metabolic (reduced base excess) and respiratory (increased partial pressure of carbon dioxide) responses (Vannucchi *et al.* 2012).

The results of this study contribute to the existing understanding of twin vs single lamb metabolism and can be applied to research with a focus on lamb survival, particularly twin, or multiple lamb survival. These deficiencies in AA concentrations early in life may explain some physiological disadvantages that twin lambs endure from birth. All results from this study provide a contribution to baseline knowledge that can be considered during future experimental applications.

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Performance variation in Brahman steers supplemented with molasses and urea

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Cattle in Northern Australia often graze low protein pastures. Supplementation of beef cattle with protein or non-protein nitrogen improves growth (Poppi and McLennan 2010). Plant-based protein supplementation can carry a significant cost to a producer, with urea being a more cost-effective option. Urea supplementation to cattle in Northern Australia is a common practice though more research is required to better understand the individual cattle variation in response to urea supplements. It was hypothesized that there is significant variation in the growth response to urea supplementation in Brahman steers.

This trial was conducted at the Queensland Animal Science Precinct in southeast Queensland and consisted of 24 Brahman steers with 238 ± 29 kg initial live weight (LW). Approval was granted by the University of Queensland Animal ethics committee. Steers were separated into two groups, based on initial LW, and randomly allocated to individual pens (3x10m) with ad libitum water, concrete floors with rubber mats on half and shade on half of the pen. After 7 days of adaptation to the facilities, steers received a low-quality Rhodes-grass hay (Control diet, 6.5% crude protein (CP)) for 56 days. Hay was offered ad libitum, with daily adjustments to maintain refusals around 5%. Steers were weighed on two consecutive days, every fortnight, and average daily gain (ADG) calculated by regressing LW over time. After this period, the steers received the same low-quality hay and a urea-molasses supplement with 8% of urea (M8U). The M8U was offered at approximately 10% of hay intake on an as fed basis, to supply 40 g urea per day (Urea diet, 8.1% CP). After 8 days of diet adaptation, the steers were weighed and diet intake and ADG measured for 56 days as described for the Control diet. The response to the urea supplement was calculated as ADG on the Urea diet – ADG on the Control diet. One steer had very low performance during the Control diet (-360 g/d) and was removed from the analysis.

This trial identified the large variation in performance of Brahman steers on a low-protein diet, with ADG ranging from –125 to 181 g/d with an average of 64 g/d. Thirty percent of the steers gained above 100 g/d, while 22% of the steers were losing weight (Fig. 1). The average response to the urea supplement was an increase of 202 g/d in ADG, varying from –11 g/d to 480 g/d. The increase in ADG with the urea supplement was less than 200 g/d for 43% of the steers, which can result in higher feeding cost per kg of extra gain. Considering that the steers consumed on average 500 g of the M8U supplement per day, at a cost of $500/tonne, the daily cost of supplement was $0.25/steer per day (not considering freight or on-farm costs associated with urea supplementation). Considering the current value of $5/kg LW for a growing steer and the average response to supplementation of 200 g/d, the benefit of urea supplementation was $1/steer per day and the average benefit-cost ratio was 4:1 (four dollars returned for each dollar invested). In the current experiment, the benefit-cost ratio would be below 2:1 to 30% of the steers (<100 g/d of response to supplement) and above 5:1 to 30% of the steers (>250 g/d or response to supplement).

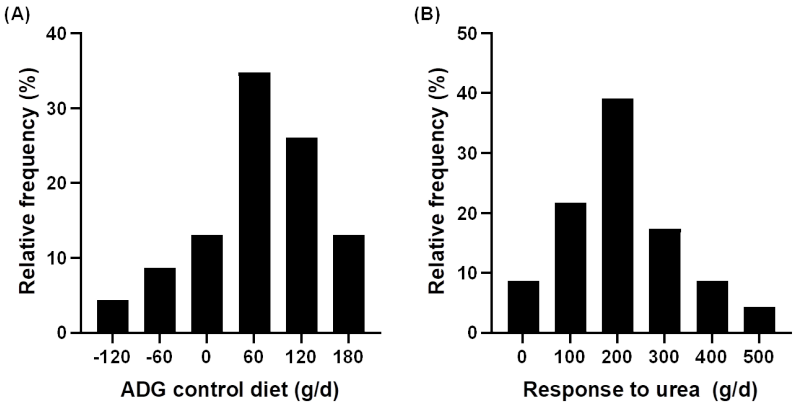

Fig. 1. Variation in growth performance of 23 Brahman steers on a low-protein diet (A) and response to a urea supplement (B).

In conclusion, this trial has shown significant variation between Brahman steers performance on the control diet and their response to a urea supplement, demonstrating the potential value from early identification of steers that are both able to perform well on low quality feeds and benefit from supplementation. Eliminating steers that will not benefit from supplementation would allow the industry to minimize expenses on this portion of the group of steers. Future studies are progressing to validate a practical tool for early identification of steers with low or high predicted response to a urea supplement.

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Poll genotype or phenotype are not associated with growth performance in tropical beef breeds

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Increasingly the northern beef industry is selecting for more polled animals. However, a common industry perception is this selection will be associated with decreased performance. Single trait selection for any trait can lead to genetically inferior animals and this could occur if selection was only to occur for polled. From a selection viewpoint it is important to establish if the polled locus is genetically linked to other economically important traits. The recording and design of the Repronomics project (Johnston *et al.* 2017) provides a unique dataset to examine the association between polled status (both genotypic and phenotypic) and early growth traits. This was achieved by analysing the effects of polled status within large half sib-families where the polled gene is segregating in 3 tropically adapted beef breeds (*viz.* Brahman, Droughtmaster and Santa Gertrudis).

Data analysed was a subset of the Repronomics project (N = 3,493) representing 2016–2020 calf drops from the Department of Agriculture and Fisheries (DAF) research herds (*viz.* Brian Pastures and Spyglass Research Facilities) that had both DNA polled/horn genotype (i.e. GENO = HH, PH, PP) and horn status phenotype (i.e. HORN = horned, polled, scurred) recorded at branding (approximately 3-4 months of age). Horns and scurs were removed and males castrated at the branding event. Growth traits analysed included birth weight, branding weight, post-branding weight gain, weaning weight, 400 d weight and postweaning average daily gain. At weaning all heifers and steers were split and managed in separated groups.

Statistical analyses were performed using SAS (SAS Institute Inc. Cary, NC, USA). For each trait the base model included fixed effects associated with the experimental design: cohort (i.e. location, year), dam age, birth month and sex. The base model was run including the effect of GENO (3 levels) and a separate model including the effect of HORN (3 levels). Each model included a term for sire nested within the effects of GENO and HORN as a random effect. This term was used in the denominator (instead of error term) as a test of significance for the GENO and HORN effects.

Table 1. Significance and least squares means for GENO, HORN and SEX effects on early growth traits in tropical beef breeds

Effect	Level	Least squares means					
		Birth weight (kg)	Branding weight (kg)	Post branding gain (kg)	Weaning weight (kg)	Postweaning ADG (kg/d)	400 d weight (kg)
GENO	HH	33.7	124.7	57.6	182.2	0.38	282.7
	PH	33.7	125.1	59.6	185.1	0.39	286.4
	PP	34.7	123.8	60.8	184.0	0.39	289.0
	P-value	0.30	0.85	**0.06**	0.31	0.53	0.26
HORN	HORNED	33.6	124.1	57.7	181.9	0.38	281.9
	POLLED	33.7	122.8	59.6	182.4	0.39	284.2
	SCURRED	33.4	126.6	59.7	185.9	0.38	286.0
	P-value	0.87	0.22	0.14	0.29	0.71	0.40
SEX	Heifer	32.7	119.4	58.5	177.9	-	-
	Bull/Steer	35.4	129.7	60.1	189.6	-	-
	P-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	-	-

Table 1 presents test of significance and least squares means estimates for the effects of GENO and HORN, and for comparison, the effect of sex. The GENO and HORN effects were not significantly associated with early growth traits in our data. The only exception was post branding weight gain (to weaning), where the GENO effect was trending towards significant ($P < 0.06$) and to a lesser extent for the HORN effect ($P = 0.14$). The LSM shows animals with HH genotype had a 2–3 kg lower post-branding weight gain compared to PH and PP animals. Large differences were observed between the sexes for all traits and LSMs showed birth and branding weights of (entire) males were heavier than heifers but the differences were reduced post branding suggesting effect of castration and/or lower hormone production reduced steer performance compared to the heifers. Further analyses can be undertaken using the same data to investigate possible effects on other traits and there is potential to examine the genomic structure on these data using high density SNP panels and whole genome sequence data.

This study has shown that selection can occur for either genotypic or phenotypic polled status without influencing growth performance however the genetic merit of selection candidates should be assessed separately using growth EBVs.

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We acknowledge the funding from MLA and MLA Donor Company and collaborating organisations and staff associated with the Repronomics Project.

Development of a mixed microbial drench for detoxification of three Leucaena cultivars

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The adoption of *Leucaena leucocephala* in Queensland, as a high protein, leguminous fodder shrub, has been hindered by insect infestation, with psyllids thriving on Leucaena planted in high humidity regions. A psyllid-resistant cultivar of Leucaena has therefore been developed (Redlands). Nonetheless, all Leucaena cultivars contain the non-protein amino acid, mimosine, which in the rumen of cattle can be degraded by many different bacteria to the toxic metabolite 3-hydroxy-4-(1H)-pyridone (3,4-DHP). For over 20 years, a mixed microbial drench containing *Synergistes jonesii* has been produced by DAF to degrade mimosine, 3, 4-DHP and its degradation product 2,3-dihydroxypyridine (2,3-DHP), to reduce any toxic side-effects of feeding Leucaena to cattle (Klieve *et al*. 2002). This drench is produced in an *in-vitro* fermentation system supplied with leaf material from the Leucaena cultivar, Cunningham. Previous research found replacing the Cunningham leaf with either psyllid-resistant Redlands or psyllid-tolerant Wondergraze leaf, negatively impacted the mixed bacterial populations' ability to degrade 3,4-DHP (Ouwerkerk *et al*. 2019). This study aimed to test how supplying leaf material from a combination of three cultivars, Cunningham, Redlands and Wondergraze of Leucaena (TriMix) to the fermentation system, would affect *S. jonesii* populations, the ability of the mixed microbial populations to degrade mimosine, 3,4-DHP and 2,3 DHP and if these microbial populations would grow and retain activity, in fermentations supplied leaf from each single Leucaena cultivar.

The first fermentation (TriMix) was initially inoculated with three cryopreserved microbial starters of fermenter fluid harvested from the final day (day 30) of three respective, single-cultivar fermentations. The TriMix fermentation was supplied daily with a three-cultivar leaf combination and ran for 30 days. Daily subsamples of fermenter fluid were collected and stored at –20°C for further analysis. On the final day of the Trimix fermentation, fermenter fluid was harvested and cryopreserved as future starter material. Three further fermentations were then conducted, each supplied on the first day of fermentation with cryopreserved microbial starter from the initial TriMix fermentation. Each fermentation was supplied with leaf material from a single Leucaena cultivar and ran for a 30-day duration, with sub-samples of fermenter fluid collected daily. All daily subsamples of fermenter fluid were analysed for (a) toxin breakdown, determined by degradation assays and HPLC; and (b) daily *S. jonesii* numbers, determined by quantitative PCR (Fig. 1).

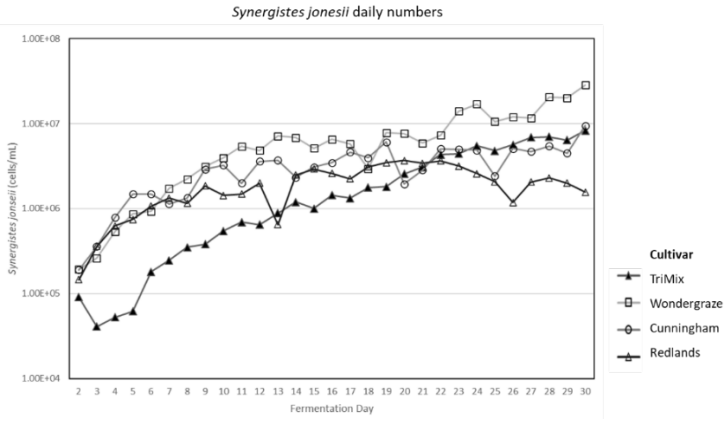

Fig. 1. Daily *S. jonesii* population numbers (cells/mL) determined by qPCR, for four fermentations: TriMix (fed leaf from all three cultivars); and three subsequent fermentations (fed leaf from a single cultivar, either Wondergraze, Cunningham or Redlands).

While the TriMix fermentation had an initial reduction in *S. jonesii* numbers, by 15 days of fermentation the *S. jonesii* numbers had increased to concentrations >10^6 cells/mL (Fig. 1). In all subsequent fermentations inoculated with the TriMix starter and supplied with leaf from a single cultivar, this initial decline in *S. jonesii* numbers did not occur, instead there was a rapid increase in *S. jonesii* numbers from the first day of fermentation (Fig. 1). In addition, all four fermentations were able to effectively degrade mimosine, 3,4-DHP and 2,3-DHP in toxin degradation assays undertaken every 5 days, from day 10 of the fermentation. This study showed that the microbial populations of the fermenter system could adapt to the nutritional and chemical composition of three different Leucaena cultivars and that a mixed microbial drench could be developed to provide similar numbers of *S. jonesii* to the original formulation, to be used to facilitate toxin breakdown in cattle grazing psyllid-resistant Leucaena cultivars.

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Do Queensland cattle possess rumen bacteria capable of degrading Leucaena toxins?

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Leucaena leucocephala is a leguminous fodder tree used by northern Australian producers to provide protein and boost the weight gains of extensively grazing cattle. There is a range of commercial Leucaena cultivars available which all contain a toxic non-protein amino acid, mimosine. Many rumen bacteria can degrade mimosine to 3,4-dihydroxy-pyridine (3,4-DHP), which is also toxic to cattle. To enable cattle to safely gain the full benefits of Leucaena, a bacterium, *Synergistes jonesii*, was isolated that could degrade the toxic metabolites 3,4 DHP and 2,3-hydroxypyridine (2,3-DHP) (Allison *et al*. 1992). A fermenter-grown mixed bacterial inoculum, containing *S. jonesii*, has been produced by DAF for over 20 years as an oral drench for cattle to prevent Leucaena toxicity and maximise weight gains (Klieve *et al.* 2002).

The necessity for this inoculum has been a contentious topic with speculation that Australian cattle now all possess rumen microbial populations capable of breaking down the three Leucaena toxins. The aim of this research is to survey cattle for rumen bacteria able to completely degrade all three of the Leucaena toxins, mimosine, 3,4-DHP and 2,3-DHP.

A survey was developed, and animal ethics approval obtained, to sample the rumen of cattle on properties throughout Queensland, in a randomised experimental design with four treatments consisting of different production scenarios with the experimental unit being the property. The treatments included properties where cattle have: (1) never received the DAF inoculum but are grazed on Leucaena; (2) received either rumen fluid from the original CSIRO cattle or the fistulated cattle held at Brian Pastures Research Station (pre-1993) and have not received the DAF inoculum and are grazed on Leucaena; (3) received the DAF inoculum and are grazing Leucaena; or (4) never been exposed to Leucaena (naïve).

In total, the survey will visit a minimum of three and maximum of five properties or research stations for each treatment and the primary variable is the concentration of the Leucaena-associated toxins mimosine, 3,4-DHP and 2,3-DHP. A mobile laboratory, including a portable incubator and micro-centrifuge, was established to enable crush-side processing and immediate incubation of collected rumen fluid, in toxin degradation assays. Cattle were rumen sampled via a stomach tube to obtain samples of rumen contents. Duplicate 10 mL volumes of the freshly collected rumen fluid were pipetted into pre-gassed Hungate tubes, an aliquot of one of the three purified toxins added and, after mixing, a time 0 (h) subsample was removed and frozen on dry ice. The Hungate tubes were placed into the portable incubator at 39°C, with further samples taken after 48 h and 168 h incubation. The concentration of the three toxins in the degradation assay subsamples were determined using high performance liquid chromatography (HPLC) (Lowry *et al.* 1985).

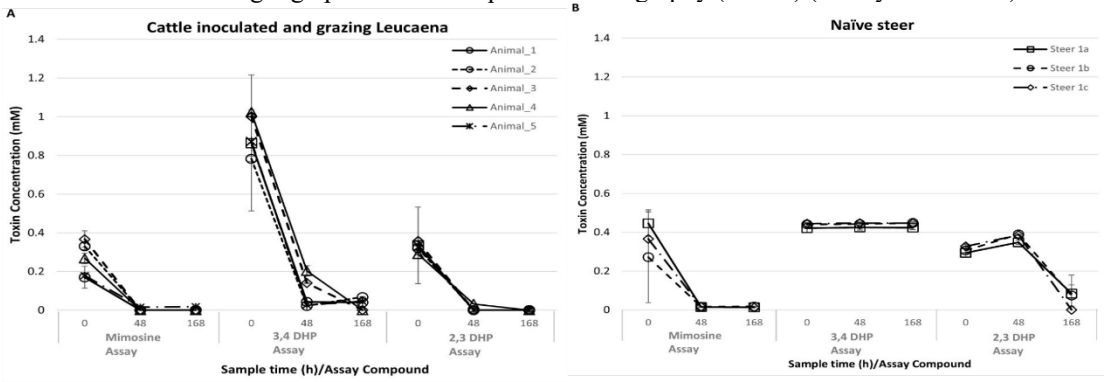

Fig. 1. Degradation assay of mimosine, 3,4-DHP or 2,3-DHP at time 0 (h), 48 h and 168 h samples from (A). Five cattle (received DAF inoculum, grazing Leucaena); (B) Naïve steer (never exposed to Leucaena); three replicate assays shown.

The mobile laboratory is proving to be operationally successful with initial toxin degradation assays showing that cattle receiving the DAF inoculum and grazing Leucaena possessed rumen bacterial populations capable of completely detoxifying all three toxins (Fig.1A). A steer which had never grazed Leucaena (naïve) did possess rumen bacterial populations able to degrade mimosine within 48 h and 2,3-DHP by 168 h but the levels of 3,4-DHP remained constant indicating that this compound was not degraded by the rumen bacteria (Fig. 1B). It is anticipated that this on-property survey will provide clarification whether all cattle possess rumen microbial populations capable of breaking down the three Leucaena toxins. The results from this study will be used to develop recommendations to industry concerning the use of the DAF inoculum for cattle grazing Leucaena pasture systems.

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Capturing and quantifying the impacts of grasshoppers and locusts across central and north-west Queensland

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Over the past four years, grasshopper and locust species have been increasingly causing impacts to pastures across central and north-west Queensland. This has caused substantial damage to pastures, prevented pasture recovery on a number of properties and contributed to significant economic consequences. A *Grasshopper Impact Survey* was initiated in 2020 and re-done in 2021 with the objective of capturing comparative data and key impacts across the affected regions, with 56 and 59 business participating, respectively. Issues focussed on in the survey included grasshopper distribution and numbers, resultant pasture damage, management responses and estimated economic impact. When grasshopper populations started emerging in 2018 producers were unprepared in terms of planning or budgeting for the impacts. However, this earlier experience allowed producers to be adaptive in their management practices during the population boom in 2021. These practices still came at a cost to producers.

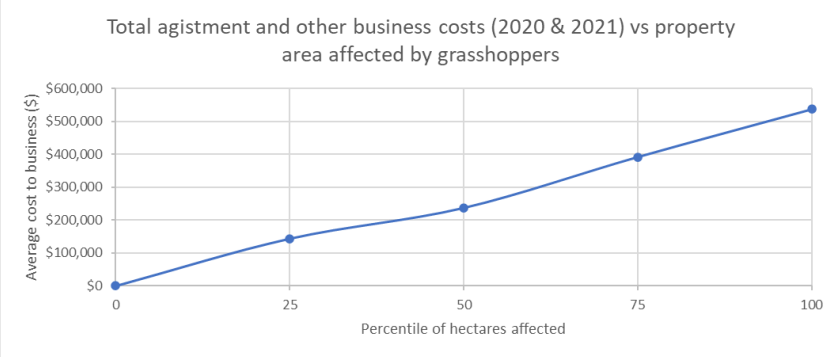

Fig. 1. Business costs in comparison to the area of property affected by grasshoppers.

Fig. 1 represents the average cost to business in relation to the area impacted on properties. The graph shows a strong positive relationship, with the cost to the businesses increasing with increasing amount of area affected. Based on the best available information provided through the 2021 producer survey, the total costs recognised by the 59 participating businesses is estimated at $18 343 500 for the 2020 and 2021 seasons. Therefore, the total cost per hectare, based on the responses provided within the survey, was estimated at $14.02/ha over the two years. This figure is comprised of increased costs including agistment, transport, supplementary feeding, time, labour, and spraying. In addition, there were significant foregone opportunities through early weaning, delayed restocking and an inability to retain stock numbers which, in turn, meant reduced wool clips and live weight turnoff. Adaptations included implementation of practices such as earlier weaning and culling; planned sales or earlier sourcing of agistment; delaying the purchase of stock in response to rain; forage budgeting and implementation of possible grasshopper control methods.

The Grasshopper Working Group instigated Emergency Use Permit's for the two chemicals Fenitrothion and Fipronil to allow an option for producers to spray grasshoppers on pastures in the Mitchell grass bioregion. An option for producers to use on organic-certified properties was Green Guard®, a bio-insecticide containing a naturally occurring Australian fungus, *Metarhizium anisopliae* var. *acridum*, mixed with a spray oil.

Grasshopper numbers began to decline in March/April 2021 with the onset of colder weather and the assumed increase in predator populations. Colder weather as explained in Rentz *et al.* (2003), causes species to go into a diapause state, meaning their development becomes suspended. In conclusion, from the data provided it can be observed that there has been significant impact from grasshoppers in the past four years, 2018-2021. Research into the ecology and life cycle of species and population prediction modelling is advocated to guide towards preparing producers for possible population increased for implementation of more timely management practices.

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I acknowledge Jenny Milson (DAF Longreach) for all her help on this work, the producers who responded to the survey and willingly shared their observations, Australian Plague Locust Commission (Chris Adriaansen and Clare Mulcahy), Winton Shire Council (Gavin Baskett and Cathy White), and Department of Agriculture and Fisheries staff: Hugh Brier, Pieter Conradie, Debra Corbett, Annette Read, Khaled Saifullah, Michelle Smith, Richard Watts, Lara Landsberg, Tim Moravek and Susie Brodie.

Functional analysis of leptin gene in West African dwarf (WAD) goats reared in Northern Cross River State

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Goats (*Capra hircus*) are identified as important livestock specie, widely distributed within different agro-ecological zones. This animal is commonly referred to as the poor man's bank, being a source of income for rural dwellers who own them as an indication of wealth (Bitto, 2008). The goat flock in Nigeria is dominated by West African Dwarf type which possesses inherent important genetic attributes. Leptin (LEP) gene is a 16-kilodalton protein (polypeptide hormone) which is secreted predominantly in the adipose tissue and affects a number of processes in the body. LEP control feed intake, energy expenditure to maintain the energy equilibrium, including regulating reproductive functions and immune response (Kulig *et al*. 2009). The attributes make leptin a strong candidate gene for assessing genetic polymorphism. The aim of this study was to carryout functional analysis of coding non-synonymous single nucleotide polymorphism (nsSNP) leptin gene in WAD goats reared in the northern part of Cross River State using protein effect analyser (PROVEAN).

The study was carried out on WAD within the northern part of Cross River State, which comprised of 21 villages. Forty-two blood samples were obtained for the analysis. Blood (6–8 mL) was obtained through jugular vein puncture and collected in EDTA (ethylenediamine tetraacetic acid) bottle for DNA extraction and genotyping. *In silico* functional examination of missense transformations were obtained utilising PROVEAN with edge estimation of 2.5. PROVEAN utilizing BLAST (ver.2.2.25) with an E-esteem limit of 0.1. the arrangements were cluster dependent on a succession character of 80% to expel repetition utilizing the CD-HIT program (ver.4.5.5) (Li and Godzik 2006). In the event that the PROVEAN score is smaller than or equivalent to a given edge, the variety is anticipated as malicious (Choi *et al*. 2012).

Functional examination of coding nsSNP of leptin gene of goat from within the study area is presented in Table 1. Ten amino acid substitutions situated in the coding region of goats were gotten from arrangement of inferred amino acid groupings of goats. Eight of the amino acid substitutions (G3G, A15G, A20C, G31A, R40L, H45C, M180V and N200L) were returned neutral. This result showed that most of the amino acid substitutions did not affect protein functions. However, the functional analysis of coding nsSNP of leptin gene from goat is crucial to reflect on the beneficial amino acid substitutions (Dauda *et al*. 2018). More so, functional analysis of nsSNP performed using PROVEAN revealed that the amino acid substitution was both harmful and beneficial.

The usefulness of nsSNP observed in this study, reveals that genetic improvement of goats at the leptin locus can be achieved in future research studies.

Table 1. Functional analysis of coding nsSNP of leptin gene of goat in Northern Cross River State

Variants	Provean	Prediction
G3G	–1.286	Neutral
A15G	–0.681	Neutral
A20C	–1.230	Neutral
G31A	–1.421	Neutral
R40L	0.200	Neutral
H45C	–1.245	Neutral
D100L	–4.320	Deleterious
H125A	3.00	Deleterious
M180V	0.189	Neutral
N200L	–1.546	Neutral

Default-threshold is –2.5 that is variant with PROVEAN score equal or below –2.5 are considered deleterious while variant with PROVEAN score above –2.5 are neutral. G = glycine, A = alanine, L = lysine, M = methionine, V = valine, R = arginine, N = asparagine, D = aspartic acid, C = cystine, H = histidine.

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The carcass and meat quality of Australian lambs diagnosed with acute, subclinical hypocalcaemia

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Hypocalcaemia is diagnosed when serum calcium content is lower than normal, to the detriment of animal activity and responsiveness to stimuli. In severe cases, hypocalcaemia will result in animal death. It is more common in pregnant or lactating ewes, however dry and male sheep may become hypocalcaemic when reared on calcium limiting feeds and then exposed to a sudden stressor event, such as shearing or transportation. Transportation is a stressor experienced by all lambs slaughtered for meat production and is associated with meat quality defects. Calcium is a bioactive mineral associated with *post-mortem* glycolysis, as well as the water-holding capacity and tenderness of meat. This study examined the carcass and meat quality of lambs diagnosed with acute subclinical hypocalcaemia to lambs with adequate serum calcium concentration. It was hypothesised that the carcasses and meat from hypocalcaemic lambs would be calcium limited and of lesser quality.

The design and execution of this feeding study is described in Newell *et al.* (2020), having been approved by the NSW DPI animal ethics committee (ORA 18/21/022). Crossbred ewe lambs were reared, for 28 days, on a combination of annual or perennial wheat that was fed with or without lucerne (4 dietary treatments). The lambs were transported and slaughtered at a commercial Australian abattoir, whereupon blood samples were collected immediately following jugular severance. Serum was separated via centrifugation and analysed for mineral content, using inductively coupled plasma-atomic emission spectroscopy (710-ES, Varian Inc.). Serum calcium content was used to diagnose lambs (*post-hoc*) as having acute subclinical hypocalcaemia (< 70 mg/L, $\bar{X}$ = 53.1 ± 12.5, n = 8) or normal calcium content (≥ 88 mg/L, $\bar{X}$ = 117.5 ± 8.9, n = 31). The latter lambs were used as the control group. Lamb carcasses were dressed and exposed to medium voltage electrical stimulation. In the chiller, a calibrated pH meter (IJ-44, TPS Ltd.) was used to evaluate the left *longissimus lumborum* muscle (LL). The pH data was used to calculate the LL pH at 18 °C (PH18), LL temperature at pH 6 (TEMP6), and final pH at 24 h *post-mortem* (PH24). Core samples, removed from the pH measurement site, were analysed for glycogen content (mmol/kg fresh weight). The next day, both LL were removed, measured for fresh colour using a colorimeter (D65-2°, Minolta), and wet aged for 5 days. These were sectioned and analysed for drip, purge and cook loss (water holding capacity parameters); fresh colour as well as for shear force (tenderness) (Holman *et al.* 2021). Data were analysed in Genstat (21st Edition) using linear mixed models fitted with the fixed effect of diagnosis (hypocalcaemia vs. control); the random effects of dietary treatment; and only for PH24, TEMP24 as a covariate.

There were no significant differences observed for lamb carcass or meat quality parameters (Table 1). The pH parameters of all lambs were found to 'hit the window' and achieve *post-mortem* glycolysis rates defined for good everyday eating quality. There was also an absence of any effect on (pH dependent) glycogen and fresh colour data (P > 0.05). The water holding capacity parameters of DRIP, PURGE and COOK were comparable between the control and hypocalcaemic lambs. Shear force results indicated likely consumer satisfaction, irrespective of diagnosis, in terms of overall liking and tenderness, according to Hopkins *et al.* (2006).

Table 1. Carcass and meat quality of lambs diagnosed with acute subclinical hypocalcaemia or normal serum calcium levels[A], including loin pH (PH18), loin temperature at pH6 (TEMP6), loin pH 24 h *post-mortem* (PH24), muscle glycogen (Glycogen), fresh colour lightness (L*), redness (a*) and yellowness (b*), drip loss (DRIP), muscle purge (PURGE), cooking loss (COOK) and shear force (SF)

	PH18	TEMP6	PH24	Glycogen	L*	a*	b*	DRIP	PURGE	COOK	SF
Normal	5.87	19.0	5.51	199.8	33.1	20.5	2.6	1.5	7.2	20.5	24.3
Hypocalcaemia	5.89	18.7	5.51	183.2	32.6	20.7	2.4	1.2	6.8	20.4	26.9
SEM	0.06	1.9	0.02	25.5	0.5	0.4	0.3	0.4	0.4	0.8	2.2
P-value	0.708	0.864	0.646	0.518	0.302	0.615	0.576	0.482	0.234	0.746	0.233

[A]Values are least-square means, standard error of the mean (SEM) and the level of significance (*P*-value).

This study demonstrated that acute subclinical hypocalcaemia, diagnosed at the point of slaughter, does not compromise the carcass or quality of lamb meat. The reserves of the LL tissue suggest that calcium was not limited in hypocalcaemic lambs and this may have offered some countenance to quality defects. Research findings do suggest the rejection of the hypothesis, however additional research with more lambs is first required to achieve a more in-depth understanding of this relationship.

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Evaluation of lactation performance identifies superior sire in Anglo Nubian dairy goat herd

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Anglo Nubian goats are commonly considered poor milk-producers among Australian dairy goat breeds and fall short of the 300+ day lactations desired in commercial dairies (Abud and Stubbs 2009). Anglo Nubians have milk with a high % of fat and protein however, lower overall milk production results in low total fat and protein yields. Markets for Australian goat milk include whole milk, cheese, yoghurt, and milk powder, meaning that both quality and quantity of milk are commercially relevant. Lactation recording can identify animals with superior milk production traits including lactation length, total milk, fat and protein yield. Understanding the performance of related animals forms the basis of a breeding program, therefore sire identification is critical (Lindsay and Skerritt 2003). The aim of this paper is to demonstrate the benefit of lactation recording to identify sires of high producing does in a case study Anglo Nubian herd.

The case study herd of Anglo Nubians goats (of known parentage) registered with the Dairy Goat Society of Australia (DGSA), was located 15 km north of Rockhampton, Australia. Milk production (lactation length, milk yield, fat and protein % and yield) was monitored over three lactations from 2014 to 2021. Lactating does were managed as a single group with *ad libitum* access to forage oat or sorghum hay during the day and lucerne hay overnight. Each doe was fed 2 kg/day of a grain ration (17.25% crude protein;12.53 MJ/kg metabolisable energy, as fed). Milk production of does was recorded according to the Herd Recording production test rules of the DGSA (DGSA 2021). Does were kidded annually in batches from July to October and milk recorded until drying off due to subsequent pregnancy. Milk samples were analysed for fat and protein using a Bentley Fourier Transform Spectrometer component analyser and lactation summaries compiled by Dairy Express, Agricultural Business Research Institute, Australia. Lactation data were analysed by residual maximum likelihood with fixed effects of sire and lactation and random effects of sire.doe. Pairwise comparison of means was performed by least significant difference tests at the 5% probability level.

A summary of mean lactation components for does sired by 4 bucks, over 3 lactations, is presented in Table 1. All variables had a significant interaction between lactation number and sire ($P < 0.05$). Results show that Sire A produced does with the longest and most constant lactation lengths (range 292 - 304), and the greatest milk yields which increased with lactation number. Sire A daughters also produced the greatest yield of fat and protein compared to does sired by other bucks. Fat and protein % of milk from these does ranged from 3.82% to 4.21% and 3.52% and 3.63%, respectively.

Table 1. Anglo Nubian milk production components by lactation number and sire[A]

Sire	Lactation number	Number of does	Lactation length (days)	Total milk yield (kg)	Total fat yield (kg)	Total protein yield (kg)
A	1	9	292^{a}	771^{cd}	31^{cd}	27^{cd}
A	2	7	303^{a}	1,080^{b}	41^{b}	38^{b}
A	3	3	304^{a}	1,328^{a}	56^{a}	48^{a}
B	1	7	228^{bc}	496^{eg}	21^{e}	17^{e}
B	2	4	227^{bcd}	679^{cdef}	27de	22de
B	3	1	270^{abc}	817^{cde}	30^{bcde}	26^{cde}
D	1	3	273^{ab}	648^{defg}	27de	22de
D	2	3	298^{a}	895^{bc}	40^{bc}	32^{bc}
D	3	3	216^{cdef}	675^{defg}	29de	23de
E	1	9	226^{cde}	517^{efg}	24^{e}	19^{e}
E	2	4	182^{ef}	653^{defg}	28de	23de
E	3	3	169^{f}	512^{efg}	20^{e}	18^{e}
Average s.e.d.			24	102	5.1	3.6

[A]Means not followed by a common letter are statistically different at $P = 0.05$. Significance letters sorted in descending order.

Lactation recording of the Anglo Nubian herd in this case study identified one buck, Sire A, that consistently sired more productive does that by the second and third lactation, had reached the commercially desirable 300+ day lactation length. The same does also produced higher fat and protein yields as a function of fat and protein % and total milk yields. This study has demonstrated the importance of lactation recording as a breeding support tool, but also identified an Anglo Nubian sire that produces doe progeny approaching commercial relevance. Whilst other Australian breeds dominate commercial goat dairies due to higher production (Abud and Stubbs 2009), it may be possible to use tools such as lactation recording to select Anglo Nubians that complement these breeding programs. It is recommended that all dairy goat breeders utilise lactation recording as a breeding tool when selecting for genetic improvement.

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Non-structural carbohydrate content of the mixed ration affects both pasture and total intake of dairy cows via mechanisms explained by the hepatic oxidation theory

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Feed intake is the single most important factor driving milk yield in dairy systems. Partial mixed ration (PMR) feeding systems incorporate conserved forages and concentrates, combined in a mixed ration, into a grazing system. These systems have become the most common within the sub-tropical Queensland dairy industry; however, feed intake in PMR systems is highly variable (2012 Queensland dairy farm survey showed 12.2 to 25.0 kg dry matter (DM)/day, unpubl. data). Part of this variability is likely due to the two distinct feed types (mixed ration and pasture) having varying effects on intake. Ison *et al.* (2020*a*, 2020*b*) illustrated that pasture structure and allocation have significant effects on intake within sub-tropical PMR systems. Auldist *et al.* (2014) found that increasing the crude protein (CP) content of the mixed ration increased pasture intake for dairy cows in the temperate region of Australia. This current study was conducted to determine how the nutrient profile of the mixed ration affects pasture and total intake in the sub-tropical region. Three diets were formulated to be isoenergetic but vary in non-structural carbohydrates (NSC; starch and sugars), CP and fibre content. The differences in nutrient profiles were achieved by altering the proportion of wheat grain, canola meal and soyhulls within the mixed ration. Soyhulls were used as a non-forage fibre source so that the physical properties of the mixed ration were not affected. The experiment was conducted at the Gatton Research Dairy during spring in 2020. Thirty-six lactating Holstein-Friesian dairy cows were randomly allocated to one of the three experimental diets; High NSC; High CP or High Fibre. Targeted feed allocations were 15.5 kg DM/day of the mixed ration on a feed pad during the day and 8.0 kg DM/day of lucerne (*Medicago sativa* L.) pasture grazed overnight.

Pasture and total intake ($P < 0.001$) were significantly lower in the High NSC treatment (Table 1). Energy corrected milk (ECM) yield was significantly lower for cows in the High NSC treatment ($P < 0.001$; Table 1).

Table 1. Effect of non-structural carbohydrate (NSC), crude protein (CP) and fiber content of the diet on feed intake, nutrient content of the consumed diet and milk production of lactating cows in a partial mixed ration (PMR) system (n = 12)[A]

	High NSC	High CP	High fibre	SEM	*P*-value
Mixed ration intake (kg DM/day)	13.6	15.7	15.4	0.556	0.074
Pasture intake (kg DM/day)	6.95[a]	10.4[b]	9.26[b]	0.414	<0.001
Total intake (kg DM/day)	20.6[a]	26.1[b]	24.7[b]	0.574	<0.001
Non-structural carbohydrate (% DM)	29.4[b]	20.3[a]	19.4[a]	0.498	<0.001
Crude protein (% DM)	21.2[a]	26.8[b]	21.7[a]	0.461	<0.001
Neutral detergent fibre (% DM)	24.1[a]	30.1[b]	32.7[c]	0.119	<0.001
Energy corrected milk yield (kg/day)	15.3[a]	20.3[b]	20.0[b]	1.17	0.024

[A]Values are treatment means, standard error of the mean (SEM) and *P* values for differences between treatment means. [a-c]Mean values with a common superscript within rows are not significantly different ($P < 0.05$). DM, dry matter.

Intake and production from cows in the High CP and High Fibre treatments were not significantly different. Therefore, excess CP intake was likely lost to the environment. The NSC content of the total diet in the High NSC treatment (29.4% DM) was similar to the average of sub-tropical PMR farms (28.6% DM) surveyed in 2012. This study has illustrated that diets with an NSC similar to the industry average had a negative effect on both pasture and total intake, and ECM yield. The low ECM yield was driven by low milk fat content (2.48%) likely due to cows suffering from low milk fat syndrome. Average rumen pH was not affected by treatment in this study. Therefore, the reduction in intake was not driven by reduced cellulolysis and low rumen pH but was likely due to mechanisms explained by the hepatic oxidation theory (HOT; Allen 2020). Briefly, HOT describes the regulation of feed intake which is driven by the fuels oxidised in the liver. Propionate, the major product of NSC digestion, is the main fuel that triggers satiety and reduces feed intake. This study demonstrated that mixed rations with a high NSC content reduce feed intake via mechanisms described in HOT, not only immediately while consuming the mixed ration but also affected pasture intake. Formulating mixed rations using non-forage fibre by-products like soyhulls, may be an effective strategy for producers to reduce the negative effects on intake and production observed in high NSC diets, whilst limiting the potential negative impacts on the environment caused by excess CP intake.

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Can we breed for resistance to buffalo flies?

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Buffalo flies (BF) (*Haematobia irritans exigua*) are major pests in the northern Australian cattle industries causing production loss and welfare impacts. Control of BF currently relies mainly on chemical treatments and the use of tropically adapted breeds. There is good evidence that resistance to BF and closely related horn flies (HF) is heritable and improvement within breeds should be possible with a suitable selection strategy. However, heritability estimates have varied considerably for both BF (0.06–0.36; McKinnon *et al*. 1990; Burrow 2001) and HF (0.10–0.59; Brown *et al.* 1992; Fraga *et al.* 2004) and there have been few practical attempts to incorporate BF resistance into cattle selection programs. This variability is likely largely due to the difficulty of accurately phenotyping cattle for BF resistance because of the propensity of BF to redistribute among cattle when disturbed. In the longer term the use of biomarkers or genomic indices for resistance, which do not require direct exposure to BF for selection to occur, present the most practically attractive means of selecting for BF resistance. However, the identification of suitable indirect criteria will depend on accurate and practically feasible direct phenotyping methods. In this study we compared the accuracy of methods based on visual counting and photography, used together with image analysis, to estimate BF resistance.

Buffalo fly counts were conducted on 34 Brangus steers held in groups of five in small paddocks on seven dates through the BF season. Visual counts were made on one side of each animal and photographs captured using a Canon SX40 HS digital camera. BF numbers were later estimated from the photographs using ImageJ® image analysis software. On two additional dates in March and May, counts were conducted with the cattle held in stalls in the yards. The animals were held quietly until BF settled and visual counts conducted. The animals were then photographed from both sides using GoPro Hero5 and iPhone 6S cameras and Image J was used to estimate BF numbers. Total visual and digital counts for each method were computed for each animal.

For the paddock counts, the overall correlation between the visual and photographic counts over the 7 dates was 0.87, with correlations within dates varying from 0.74–0.85, indicating that counts by the two methods were highly correlated. For the pen counts, correlations between visual counts, photographs with a GoPro™ Hero5 camera and iPhone 6S camera within dates were also relatively high (0.61–0.95) although more variable than for the paddock counts.

Table 1. Correlations between counts on individual dates and overall paddock counts; visual and digital counts

	Paddock counts							Yard counts	
Date	12 Mar	26 Mar	09 Apr	28 Apr	07 May	09 Oct	20Jan	17 Mar	21 May
Visual	0.72***	0.73***	0.65***	0.71***	0.74***	0.72***	0.80***	0.33*	0.53**
Digital	0.74***	0.70***	0.72***	0.62***	0.80***	0.68***	0.70***	0.43**	0.41*

Values are Pearson correlation coefficients $n = 34$, $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

The correlations between paddock counts on individual dates and overall BF counts varied from 0.65 to 0.80 for visual counts and from 0.62 to 0.74 for digital counts suggesting that even an individual paddock count gave a relatively good prediction of overall susceptibility (Table 1). Accuracy increased with the use of up to four repeat counts (R = 0.95 and 0.90 for visual and photographic counts, respectively). Correlations between counts made in the yards and overall counts were lower than for paddock counts, but still significantly greater than 0 ($P < 0.05$) in all instances.

BF counts derived from photographs taken in the paddock from a camera with a telephoto lens are likely to provide the most accurate option for assessing resistance and do not require cattle to be mustered. Photographs can be taken from a distance in the paddock with minimal disturbance to cattle and later analysed to provide a permanent record of fly counts from each animal. Using repeat counts on several dates will increase accuracy. Although historically most estimates of BF numbers have been derived from yard counts and practically it is often easier to conduct counts in the yards, our results suggest that the accuracy of prediction of BF resistance will be better using paddock counts. However, even though the correlations with yard counts were lower than for paddock counts they were of a level that should enable genetic improvement to be made, particularly if multiple repeat counts are used. It should be noted that the BF counts in this study were made on relatively quiet, frequently mustered cattle. As BF redistribute when disturbed, the accuracy of phenotyping is likely to be lower with animals less used to handling. Ultimately the use of biomarkers or genomic indices presents the most practically attractive means of selecting for increased BF resistance, but in the interim the use of photographic field counts is likely to provide the most accurate method for direct phenotyping.

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Assessment of thermotolerance of Dorper and White Dorper lambs during the Australian summer

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Dorpers and White Dorpers are low maintenance meat sheep, adapted to wide range of agroecological zones in Australia. Dorpers are known for their hardiness and exceptional adaptability, have rapid weight gain, good carcass confirmation, fat distribution, and feed conversion efficiency (Zhang *et al.* 2021; Joy *et al.* 2020). This breed has either a black head (Dorper) or a white head (White Dorper), but little is known about the differences in adaptive and productive behaviors of these two strains. We conducted a preliminary study to compare the thermotolerance of Dorper and White Dorper under natural conditions during summer.

Twenty lambs (10 ewes and 10 rams; 3–4 months old) of Dorper and White Dorper strains (body weight: 23.2 ± 0.61) were studied. Based on prospective weather forecast, replicate studies were performed on a relatively cold day (T~15°C) and a relatively hot day (T~30°C). On each day, the same animals were sampled, and we measured respiration rate, heart rate and rectal temperature. We also blood sampled for prolactin assay (3 samples by venipuncture at 30 min intervals), as a signature of thermal stress (Alamer 2011). Initial and final body weights were also recorded during the collection period (6–27 February 2021). The data were analyzed using the REML variance component analysis procedure for Genstat (GenStat, 17th Edition; VSN International Ltd, Hemel Hempstead, UK).

Table 1. Mean (±SED) physiological parameters and prolactin levels in Dorper and White Dorpers during cold and hot days (*n* = 20/genotype) during summer

Variables	White Dorper		Dorper		SED	Significance (*P*-value)		
	Cold day	Hot day	Cold day	Hot day		Genotype	Temp	Genotype × Temp
Respiration rate (breaths/min)	51.3[a]	70.5[b]	46.6[a]	71.1[b]	6.48	>0.1	<0.001	>0.1
Rectal temperature (°C)	39.1[a]	39.5[b]	39.4[b]	39.8[c]	0.08	<0.001	<0.001	>0.1
Heart rate (beats/min)	122.0[a]	156.3[c]	132.1[ab]	153.0[bc]	8.01	>0.1	<0.001	>0.1
Prolactin concentration (ng/mL)	19.9[a]	58.8[b]	51.8[b]	187.5[c]	14.73	<0.001	<0.001	0.002

There was a significant effect of ambient temperature on respiration rate, rectal temperature, and heart rate (P<0.0001; Table 1) in both Dorpers and White Dorpers, with all the parameters being higher on the relatively hot day. Neither respiration rate nor heart rate differed between strains, but rectal temperature was higher ($P < 0.0001$) in Dorpers than in White Dorpers on both days. The initial and final body weights were similar in the two strains. Plasma prolactin levels were lower ($P < 0.001$; Table 1) in White Dorpers than in Dorpers on both days.

These data provide evidence of differences in thermotolerance of Dorpers and White Dorpers. Higher plasma prolactin levels in Dorpers may confer better thermotolerance (Alamer 2011) and ability to withstand heat stress, although this requires substantiation. Further research is still warranted to verify these results in a larger population and in more extreme temperatures (T > 35°C).

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Behavioural indices as means of assessing buffalo fly numbers on cattle

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Buffalo flies (BF), *Haematobia irritans exigua*, cause more than $100 million annual loss to the Australian cattle industries in terms of losses in weight gain, milk production and skin value and management costs. In addition, irritation and annoyance due to biting of BF have significant welfare impacts. Current BF control measures are heavily reliant on chemical treatments, but resistance to chemicals is widespread. Breeding cattle resistant to BF could help reduce BF impacts and costs of production. Although there is well documented variation among cattle in susceptibility to BF, accurately phenotyping animals for BF resistance is difficult and practical methods of assessing resistance are needed for use in selection and breeding programs.

Infestations of BF cause a range of protective behavioural responses in cattle, including tail flicks, head tosses, ear flicks, leg stomps and skin twitching. Behavioural responses have been shown to be correlated with parasite numbers in a number of other host-ectoparasite systems and may provide a more practical and potentially more accurate method of estimating buffalo fly susceptibility in cattle than the use of direct BF counts.

This study assessed the relationship between BF numbers and BF avoidance behaviours with a view to the use of automated measurement of behaviours by methods such as accelerometer ear tags, as an indicator of BF resistance. Buffalo fly numbers on 34, 2-year-old Brangus steers were recorded by visual and photographic techniques on nine different dates during the BF season in 2020 and 2021. Average BF count across the nine dates was used as an estimate of BF susceptibility for each animal. In addition, the behaviours of individual steers were recorded visually by an observer in 2-min periods in the morning of each observation day. Animals were observed in groups of five in an open fenced area from a distance of 3–5 m.

Table 1. Pearson (Spearman rank) correlations between mean visually and photographically assessed buffalo fly (BF) counts on cattle and the total frequency of BF-related avoidance behaviours of cattle over all dates

	All behaviour	Head tosses	Ear flicks	Tail flicks	Foot stamps/kicks
Visual BF count	0.53** (0.71)	0.53** (0.63)	0.38* (0.60)	0.49** (0.69)	0.27 (0.46)
Photographic BF count	0.68*** (0.76)	0.62*** (0.68)	0.54** (0.70)	0.60*** (0.71)	0.37* (0.54)

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. All values for Spearman correlation were significant at $P < 0.001$ except for foot stamps ($P < 0.01$).

This study demonstrates that the frequency of all BF avoidance behaviours was strongly correlated with BF counts and that there were also quite strong correlations between fly numbers and the individual behaviours assessed, although the association with foot stamps/ kicks was lower than for other behaviours (Table 1). Tail flicking was the most frequent BF avoidance behaviour (56%) observed in this study, followed by ear flicks (31%), head tosses (10%) and leg stomping (4%). The proportion of head tosses in our study was highest during months when fly numbers were high (data not shown). Similarly, Mullens *et al.* (2016) found that cattle demonstrated a greater number of head throws when high numbers of stable flies were present. Despite that head tosses made up a relatively low proportion of overall behaviours the correlation with fly counts was higher than with most other behaviours, suggesting that the measurement of head tosses may be a more specific predictor of BF numbers than other behaviours or overall avoidance behaviours. It should also be noted that the correlations reported here were recorded despite observing cattle for only 2-min periods on each observation date. It is expected that the use of accelerometers or inertial measurement units (IMU), potentially in ear tags, to provide ongoing measurement and classification of behaviour over extended periods of time may provide a more accurate assessment of cattle behavioural responses, and potentially better prediction of BF numbers. In addition, this data could be collected automatically, providing a much more practically appealing means of phenotyping for BF susceptibility. We are currently investigating this approach.

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Polyphenol and antioxidant capacity of Desmanthus

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Plants have been used throughout history for their medicinal properties. This use has often focused on human health but plants have also been applied in animal health management and methane mitigation (Rochfort *et al.* 2008). Recent interest has focussed on the extraction and concentration of plant bioactives for use as dietary additives, in particular as essential oils, polyphenols or antioxidants. However, delivery of supplements in extensive grazing systems is problematic and so efforts have been directed at providing antioxidant activity using forage crops high in antioxidants and polyphenols such as lucerne (Ponnampalam *et al.* 2020). Some polyphenols have strong antioxidant activity, for example, sugar cane-derived polyphenols improve performance in chickens (Shakeri *et al.* 2020). Also, a number of cultivars of the tropical legume Desmanthus that are purported to have relatively high condensed tannin and polyphenol concentrations have been shown to decrease methane emissions in beef cattle on relatively poor pasture (Suybeng *et al.* 2020). Therefore, the aim of this study was to characterise the polyphenol, tannin and antioxidant contents of Desmanthus.

Six accessions of Desmanthus from Northern Queensland (two from Armreynold and four from Madison) and one of lucerne grown in Western Victoria (Hamilton) were dried at 60°C and ground to 2 mm prior to extraction. Samples were analysed using our published methods (Ali *et al.* 2021). Phenolic compounds were identified by LC-ESI-QTOF/MS (Ali *et al.* 2021). Samples were analysed in triplicate and statistical analysis performed using ANOVA in Genstat Version 19.

Table 1. Phenolic content and antioxidant activity of six Desmanthus accessions

	A	B	C	D	E	F
TPC (mg GAE/g)	60.9±0.95^{b}	71.7±0.37^{a}	48.4±1.41^{c}	49.4±1.13^{c}	59.9±2.79^{b}	68.0±0.84^{a}
TFC (mg QE/g)	4.73±0.05^{b}	4.47±0.14^{b}	4.17±0.20^{b}	4.34±0.29^{b}	6.70±0.27^{a}	4.40±0.38^{b}
TCT (mg CE/g)	0.72±0.04^{c}	3.07±0.09^{a}	0.23±0.08^{d}	0.05±0.04^{e}	0.88±0.04^{c}	1.45±0.20^{b}
DPPH (mg AAE/g)	117±2.6^{c}	148±2.3^{a}	1010±2.2^{d}	103±0.7^{d}	130±3.8^{b}	133±9.2^{b}
FRAP (mg AAE/g)	12.8±0.19^{c}	18.7±0.22^{a}	10.5±0.38^{d}	11.4±0.16^{c}	15.5±0.49^{b}	15.8±0.98^{b}
ABTS (mg AAE/g)	96.9±4.38^{d}	158±4.90^{b}	104±4.97^{c}	107±8.3^{c}	101±2.0^{c}	171±1.9^{a}
•OH-RSA (mg AAE/g)	108±1.93^{b}	97.5±2.39^{c}	66.1±3.65^{d}	68.0±6.45^{d}	65.5±5.26^{d}	116±1.3^{a}
FICA (mg EDTA/g)	2.43±0.16^{b}	1.81±0.12^{c}	1.98±0.15^{c}	1.92±0.17^{c}	1.98±0.28^{c}	6.09±0.05^{a}
RPA (mg AAE/g)	100±12.7^{b}	118±8.48^{a}	66.5±3.81^{d}	70.8±4.90^{d}	81.7±5.80^{c}	107±8.5^{b}
TAC (mg AAE/g)	12.1±0.32^{a}	6.19±0.23^{b}	5.63±0.15^{b}	10.1±0.35^{a}	11.2±0.63^{a}	13.1±0.80^{a}

Values are mean ± standard deviation per gram powder weight; $n = 3$ samples per sample. Values within the same row with different superscript letters (a–e) are significantly different from each other ($P < 0.05$). TPC (total phenolic contents); TFC (total flavonoid contents); TCT (total condense tannins); DPPH (2,2′-diphenyl-1-picrylhydrazyl assay); FRAP (ferric reducing antioxidant power assay); ABTS (2,2′-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid assay); TAC (total antioxidant capacity); GAE (gallic acid equivalents); QE (quercetin equivalents); CE (catechin equivalents); AAE (ascorbic acid equivalents); RPA (reducing power assay); FICA (ferrous ion chelating activity); •OH-RSA (hydroxyl-radical scavenging activity); EDTA (ethylenediaminetetraacetic acid).

Thorough scrutiny of stored libaries allowed the characterization and identification of 68 phenolic compounds including 21 phenolic acids, 36 flavonoids, 1 lignan and 10 other polyphenols by LC-ESI-QTOF/MS (data not shown). All of the Desmanthus accessions contained very high TPC and exhibited high antioxidant activity measured by the various techniques. The average TPC (60 vs 5.7 mg GAE/g, $P < 0.001$) and TFC (4.8 vs 0.16 mg QE/g, $P < 0.001$) of Desmanthus were approximately 10- and 30-fold higher than in lucerne while TAC was 33% higher (9.70 vs 7.30 mg AAE/g, $P < 0.05$). The TPC was strongly correlated with antioxidant activity measured using the DPPH ($r = 0.96$, $P < 0.01$), FRAP ($r = 0.93$, $P < 0.01$) and RPA ($r = 0.97$, $P < 0.01$) assays. In conclusion, Desmanthus has a high TPC and antioxidant activity and may be a suitable as a grazed or conserved forage to reduce methane emissions.

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Dietary supplementation of fennel extract improves productivity and eggshell quality in Japanese laying quails

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Fennel (*Foeniculum vulgare*) is a perennial herb native to the Mediterranean region. Fennel extract contains flavonoids and Anethole (Goswami and Chatterjee 2014), which have estrogenic effects. Oestrogen is the main hormone of producing egg in laying birds; it slowly decreases in laying hen over the egg production cycle, during molting, and increases again with the beginning of egg production (Hoshino *et al.* 1988). The aim of this study was to investigate the estrogenic effects of hydro-alcoholic extract of fennel (*Foeniculum vulgare*) seed on egg production and eggshell quality in Japanese quail.

Seventy-two 40-day-old female quails were divided into two experimental groups with four replicates in a Complete Randomized Design. All quails were fed a standard commercial diet (Table 1) for 6 months, with the treatment group also receiving 350 mg fennel extract per kg of diet. Egg samples were collected every second week, from all replications of experimental groups to measure the egg quality traits. Commercial traits including egg production, egg weight, shell resistance, shell thickness, Ca content of eggshell and haugh unit were assessed and calculated. All data were analysed using Proc GLM of SAS 9.1.

Dietary supplementation of fennel extract increased egg production and quality ($P < 0.05$; Table 2). The highest amount of Ca content was observed in Fen group ($P < 0.05$), which can be due to oestrogenic effects of fennel extract and consequently resulted in higher eggshell resistance in comparison with control group ($P < 0.05$).

Conclusively, it seems dietary supplementation with fennel extract affects egg production and commercial traits especially eggshell resistance in Japanese quail.

Table 1. Composition of experimental diet

Ingredients	(% dry matter)
Corn	58.9
Soybean meal	30
Soybean oil	3.2
Dicalcium phosphate	1.2
$CaCo_3$	5.8
DL-methionine	0.2
Permix (Min+Vit)	0.5
Salt	0.2

Table 2. The effects of different zinc sources on egg parameters in broiler breeder hens

Experimental group	Control	Fennel	SEM	*P*-value
Egg yield (eggs/hen/day)	0.89^b	0.93^a	0.09	<0.0001
Egg weight (gr)	12.47^b	13.15^a	0.21	<0.0001
Eggshell weight	1.06^b	1.18^a	0.12	0.038
Eggshell resistance (gr/cm^2)	1157.8^b	1505.6^a	4.9	<0.0001
Shell thickness (mm)	0.224^b	0.23^a	0.04	<0.0001
Ca (mg/gr eggshell)	3925.4^b	4372.3^a	14.17	<0.0001
Haugh unit	85.55^b	87.89^a	0.35	<0.0001
Egg yolk index (%)	4.15^b	4.53^a	0.32	0.021

a, b: different superscript letters indicate a significant difference ($P < 0.05$).

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Stage of maturity and energy intake level influences protein and fat deposition in cross-bred lambs

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The efficiency of individual lamb growth is affected by stage of maturity, composition of gain, heat production and the nutrients supplied by the feed (Oddy *et al*. 1997). The chemical composition of a lamb's empty body changes as they approach maturity and the rate of protein deposition decreases and the rate of fat deposition increases. Not only is the energy content of protein (23.8 kJ/g) dissimilar to fat (39.6 kJ/g) but the energetic efficiency of deposition is much lower for protein than it is for fat, altering the efficiency of growth depending on the composition of gain. Protein deposition is the balance between protein synthesis and degradation, which are both energy requiring (heat producing) processes. As a result, heat production, or the animal's maintenance requirements, are closely related to whole-body protein mass (Graham *et al*. 1974). Further to this, intestinal tissues and the liver have a higher specific energy expenditure than peripheral tissues or skeletal muscle (Koong *et al*. 1982) and are both highly responsive to feed intake and the nutrient density of the feed (Oddy *et al*. 2019). Fat deposition occurs from energy not used for protein deposition or lost as heat (Oddy *et al.* 1997).

The aim of the current experiment was to use CT scans to analyse energy transactions in growing lambs at two stages of maturity and two levels of nutrient intake. CT scans were used to obtain repeat measurements of the proportion of fat and lean in the empty body on the same animals. This research will underpin development of best practice nutritional management of growing lambs and is likely to assist in improving the predictability of lamb production.

Feed intake, growth rate, body composition and diet digestibility were recorded over two periods. Lambs (n = 108) were fed a pelleted diet daily for eight weeks in a 36-pen feedlot at both four (period 1) and eight (period 2) months of age, either at a high (3.5% of liveweight) or a low intake (2.5% of liveweight). At the commencement of period two, half of the previously low intake lambs were changed to high intake and vice versa. Lambs were CT scanned at the beginning and end of both feeding periods to measure rumen volume and body composition. Digestibility of the diet, determined by a digestibility trial, did not differ with feed intake level or feeding period.

Lambs started the first feeding period at an EBW (empty body weight) of 24.7 ± 1.9 kg (mean ± SD) and grew at 190 ± 28 (high) and 77 ± 26 g/day (low) consuming 16.1 ± 0.3 and 10.0 ± 0.1 MJ ME/day respectively. Lambs previously on the low intake started the second feeding period at an EBW of 29.1 ± 1.4 kg and lambs previously on high intake at an EBW of 31.8 ± 1.7 kg. During the second period, lambs grew at 173 ± 12 (high) and 78 ± 11 g/day (low) irrespective of feeding period one intake. They were consuming 16.5 ± 0.1 (high) and 11.7 ± 0.1 (low) MJ ME/day. Fat gain was significantly greater for low intake lambs in feeding period two and protein gain was significantly greater for high intake lambs in both feeding periods (Table 1). Lambs on high intake had significantly greater estimated maintenance requirements than those on low intake in both feeding periods (Table 1).

Table 1. Energy transactions in lambs at differing stages of maturity and nutrient intake[A]

	Feeding period 1				Feeding period 2			
	High	Low	SEM	*P*-value	High	Low	SEM	*P*-value
Fat gain (g/kg)	467	500	20.7	n.s.	606[a]	724[b]	16.6	<0.001
Retained energy fat (MJ/kg)	18.5	19.8	0.8	n.s.	24.0[a]	28.7[b]	0.7	<0.001
Protein gain (g/kg)	101[a]	79[b]	5.6	<0.05	76[a]	41[b]	4.2	<0.001
Retained energy protein (MJ/kg)	2.4[a]	1.9[b]	0.1	<0.05	1.8[a]	1.0[b]	0.1	<0.001
Maintenance (MJ/day)	12.2[a]	8.4[b]	0.3	<0.001	12.0[a]	9.4[b]	0.2	<0.001

[A]Values are least-square means, standard error of the mean (SEM) and *P*-value from analysis of variance model; row-wise superscripts indicate different treatment means ($P < 0.05$).

These results demonstrate less mature lambs and lambs on higher intake are more efficient at utilising energy intake for gain. Less mature lambs deposit more energy as protein and higher energy intake results in increased energy available above maintenance requirements. Lambs on low levels of intake retained more energy as fat than expected. These results challenge the current belief that fat deposition is the difference between energy intake, energy deposited in protein and heat production.

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Timing of testing critical when determining the phosphorus (P) status of beef cattle in northern Australia

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Phosphorous (P) deficiency in northern Australia can significantly impact the productivity and profitability of beef cattle businesses due to reduced cattle growth rates, reproductive performance, and increased mortality (Bowen *et al.* 2019). Plasma inorganic P (PiP) in conjunction with estimates of diet quality from faecal analyses is the best method of diagnosing P status in cattle (Dixon *et al.* 2020). Testing should be undertaken at the end of the rainy season when protein and energy are above maintenance in the animal's diet. Appropriate timing can be challenging on extensive properties as it is most practical to undertake sampling when cattle are mustered for routine husbandry practices. Timing of testing is also more challenging in regions such as south west Queensland with highly variable and less summer dominant rainfall than the seasonally dry tropics. The Mulga Lands of south west Queensland are considered P deficient, and common industry practice is to have two musters per year (Bowen and Chudleigh 2021). Therefore, the objective of this work was to determine if P status testing at a routine muster in June, was appropriate to determine the P status of cattle on a Mulga Lands property.

In June 2020 on a property in the Mulga Lands, 23 #8 (2018 weaned) Droughtmaster cross heifers were sampled from a mob of 170 mixed age females mustered for pregnancy testing. The heifers were grazing a 1250 ha paddock with a mix of red and black soil types dominated by mulga *(Acacia aneura)* and herbage species. The heifers selected for sampling were pregnancy tested as 5+ months in calf. The animals were body condition scored (BCS) (1 = low, 5 = high), blood sampled for PiP, and dung sampled for diet quality analyses (dry matter digestibility % [DMD]). Four soil samples were collected from the paddock for soil phosphorus analysis using the Colwell P method.

Two soil samples had Colwell P levels in the deficient range (4–5 mg/kg) and two were in the adequate range (6–8 mg/kg). The sampled heifers had a BCS of 3 to 4. The average PiP of the heifers was 1.38 mmol/L with a range of 0.7–1.9 mmol/L. The average DMD of the diet was 48.3% and the non-grass component of the diet was 70.3%.

The soil sample results indicate that the grazed paddock was deficient to marginal for P (Bowen and Chudleigh 2021). Mean PiP is in the marginal range (1.1–1.6 mmol/L) (Dixon *et al.* 2020). However, the diet DMD of 48.3% is below the maintenance level of 50% required to assess P status as both diet protein and energy must be above maintenance (Dixon *et al.* 2020). The low DMD is reflective of the time of season that the sampling was conducted (June) and consistent with the diet non-grass component of the diet being 70.3%. Mulga leaves likely make up most of the non-grass component and are low in digestibility and P (Bowen and Chudleigh 2021). The low soil P, known low P content of mulga leaves and low blood PiP all indicate that P is likely to be limiting cattle performance, however the diet DMD% at this sampling time suggests that energy intake is also limiting. Therefore, an accurate assessment of the P status of the heifers cannot be determined.

The most significant learning from this study is to ensure P screening is undertaken when protein and energy levels of feed are adequate, ideally mid-late rainy season (cf. March and April). Sampling when practically convenient, as was the case with this work, did not allow for accurate assessment of the heifers' P status. More P status testing needs to be undertaken in south west Queensland and other regions with highly variable rainfall so producers, researchers and advisers can develop strategies for more effective testing and to make better use of P status information in cattle nutritional management.

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Variation in heat production and energy efficiency in lambs

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Feed accounts for over 70% of the total production costs in the Australian lamb industry, making it beneficial for producers to select animals that will utilize feed more efficiently. Efficient animals, also known as low residual feed intake (RFI) animals, eat less but have the same body weight gain and live weight as inefficient (high RFI) animals Phenotypic variation in heat production suggests the metabolism and accretion of nutrients eaten differs between lambs. Heat production can be estimated feed intake and retained energy calculated from fat and protein content of the body.

The objective of the experiment was to phenotype Merino wether lambs into high or low RFI groups, then examine variation in heat production, energy retained, and their relationship with diet quality between lambs. The experiment was divided into two phases. In Phase 1, 114 lambs were fed *ad libitum*, a diet of 50 % lucerne chaff: 50 % oaten chaff (9.3 MJ ME/kg DM, 12.6% CP) for 80 days, and body composition was estimated by computed tomography (CT) scanning of the live animals on day 0 and day 80 of feeding. The CT scan data included proportions of fat, muscle, and bone, and were used to calculate gain in each period. At the end of Phase 1, lambs were put in respiration chambers (RC) for 22 hours to measure gas production. Lambs were individually ranked by RFI at the end of Phase 1 using a combination of feed intake, live weight and average daily gain data. In Phase 2, low RFI and high RFI animals were fed diets of three different qualities (Low 9.2 MJ ME/kg DM, 11.4% CP, medium 9.5 MJ ME/kg DM, 12.6% CP, and high 11.6 MJ ME/kg DM, 14.5% CP), where medium diet was the basal diet from Phase 1. There were 10 lambs in each treatment group. During Phase 2 of the experiment, the RC measurements were repeated, and lambs were CT scanned on day 150 prior to slaughter. Heat production was measured by three methods; Brouwer's calculation, carbon dioxide, and CT scan body composition; data methods and results were compared between low and high RFI animals based on the different energy density diets.

In Phase 1, average liveweight and daily gain (ADG) were similar ($P > 0.05$) between low and high RFI lambs. Feed intake was significantly ($P < 0.05$) higher in the high RFI compared to the low RFI lambs ($P < 0.05$). High RFI lambs had significantly higher fat gain ($P < 0.001$; 20.82 g/d ± 0.83 SE) and heat production ($P < 0.001$; 10.05 MJ/d ± 0.14 SE) than low RFI lambs fat gain ($P < 0.001$; 18.17 g/d ± 0.69 SE) and heat production (9.12 MJ/d ± 0.12 SE), but there was no effect on lean gain. These results provide better understanding of the effect of different feed intake of diet on body tissue composition of lambs.

In phase 2, lambs fed the high-energy diet ate more ($P < 0.001$; 1770.8 g DM ± 62.7 SE) and produced more heat ($P < 0.001$; 13.84 MJ/d ± 0.46 SE) than lambs fed a low-energy diet ($P < 0.001$; 1377 g DM ± 45.3 SE) with less heat production ($P<0.05$; 9.17 MJ/d ± 1.22 SE). There was significant effect of RFI phenotype and diet on heat production (Table 1). High RFI lambs had significantly ($P < 0.05$) higher feed intake, live weight, fat gain, metabolisable energy intake, retained energy, heat production than low RFI animals fed on high energy diet. These variables did not differ ($P > 0.05$) between high and low RFI lambs fed on medium and low energy diets.

Table 1: The retained energy (MJ/d) and heat production (MJ/d) by body composition CT scan method is shown for low and high RFI lambs based on three different energy density diets is shown below

Variable	Diet group	Low RFI (mean ± SE)	High RFI (mean ± SE)	Significance *P*-value
Retained energy (MJ/d) by CT scan method	High diet	2.16 ± 0.13	2.76 ± 0.14	0.01
	Medium diet	1.78 ± 0.17	1.7 ± 0.16	0.49
	Low diet	1.4 ± 0.18	1.36 ± 0.08	0.23
Heat production (MJ/d) by CT scan method	High diet	12.68 ± 0.26	13.84 ± 0.46	0.01
	Medium diet	10.46 ± 0.31	10.16 ± 0.19	0.23
	Low diet	9.19 ± 0.31	9.17 ± 0.22	0.35

Our results indicate a significant increase in heat production as metabolizable energy intake increased. Based on the results, lambs with high RFI fed the high energy diet produced more heat and retained more energy compared to medium and low energy diets. Our results indicate that energy content of diet influences heat production, energy expenditure and gain in body composition as fat. In conclusion, to have a more transparent selection strategy, heat production, fat gain and residual feed intake could be included as an index with other production traits to select the most feed efficient animals.

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Prevalence of gastrointestinal parasites in small ruminant farms in Western and Northern division of Fiji

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Fiji has the largest small ruminant population of the Pacific Island countries with an estimated sheep and goat population of about 14 068 and 110 196 respectively, from 764 sheep and 8,801 goat farms (Fiji National Agricultural Census 2019). In the tropical environment of Fiji, high temperatures and rainfall strongly favour hatching and development of gastrointestinal nematodes (GIN) to the infective 3rd larval stage, although these conditions also result in short survival times of the infective larvae on pasture (Banks *et al.* 1990). The aim of this study was to quantify the prevalence of GIN infection in small ruminants in private farms in Fiji, and identify differences caused by small ruminant species, animal class (i.e. age and lactating status) or location (environment).

In this study, 17 farms were sampled from the Western (n = 8) and Northern (n = 9) divisions of Fiji including a total of n = 257 goats and n = 299 sheep. The farms were randomly selected from the Fijian Ministry of Agriculture small ruminant farm database. On each farm, ~10 animals were sampled from each of three classes per species: young animals (YA), dry females and reproductive males (DF and RM) and lactating females (LF). Faecal samples were collected directly from the rectum of individual animals. The samples were stored at 4°C until analysis for faecal egg count (FEC) by a modified McMaster technique (Whitlock 1948) using 2 g of faeces mixed with 28 ml of saturated salt solution, with a detection limit of 100 eggs per gram of faeces (epg). All statistical analysis and graphs were done using R software (R Core Team 2019) using a linear mixed effects model within the package *nlme* (Pinheiro *et al.* 2019). The data was log transformed for analysis and is presented in this form in the figures with true values in the text.

Overall, goats (2299 epg) had higher (P < 0.0001) FEC than sheep (1784 epg; Fig.1 A). An effect of animal class was also detected (P < 0.0001) showing that YA had higher FEC (2725 epg) than both DF and RM (1727 epg) and LF (1556 epg). However, adult animals did not differ in FEC independently of lactation status (Fig.1 B). The location of the farms did not affect the FEC values (P = 0.61, Western Division 1880 epg *vs* Northern Division 2139 epg, Fig.1C).

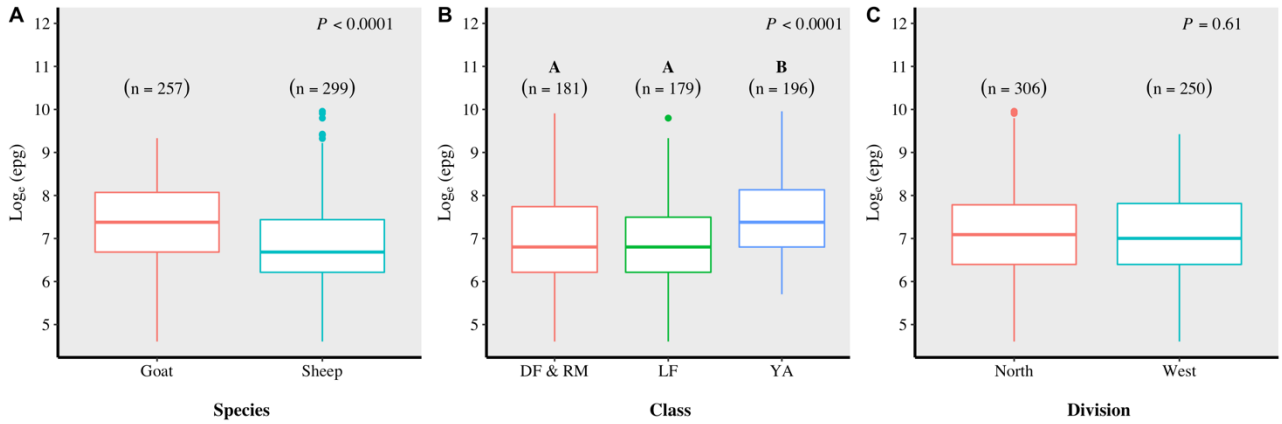

Fig. 1. The effect of species, animal class and location (i.e. Division) on faecal egg count in sheep and goats raised by smallholder farmers in Fiji. Values are least-square means in logarithmic scale; different superscripts in figure B indicate significant difference between groups (Tukey; P < 0.05).

Overall, these early results suggest a very high GIN burden widespread in small ruminant flocks in Fiji. The FEC levels detected are well above the FEC intervention thresholds recommended for sheep and goats in Australia to minimise loss of production (http://www.wormboss.com.au) so are likely associated with significant production loss. Further research on the effectiveness of current and alternative worm control strategies on smallholder small ruminant farms is required to support the productivity of Fijian farms and farmer livelihoods. In addition, the results suggest goats carry heavier burdens than sheep and young stock are the most susceptible to infection.

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Liveweight performance of cattle grazing Redlands and Wondergraze leucaena north Queensland

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Leucaena is a rapid-growing, perennial legume which has potential to intensify beef production in the northern rangelands of Australia. Adoption of leucaena in north Queensland has been limited, in-part by the prevalence of the leucaena psyllid (*Heteropsylla cubana*). Psyllid infestations cause yield losses (Bray and Woodroffe 1991) and all cultivars previously used by industry are susceptible. *Leucaena leucocephala* 'Redlands' (R) released in 2018 has genetic resistance to psyllids with potential to increase leucaena productivity in psyllid prone regions and increase adoption. However, the performance of R under commercial grazing was untested and cattle grazing a leucaena palatability trial at Whitewater Station in north Queensland, initially grazed other leucaena varieties in preference to R (Keating 2019).

To address concerns about the commercial suitability of R, a 61 ha replicated grazing trial was established at Pinnarendi near Mt Garnet (18.043ºS, 144.876ºE; 760 m asl) to compare liveweight gain between R and the widely used *Leucaena leucocephala* 'Wondergraze' (W). There are four paddocks each of R and W. Trial design, establishment and management are previously described (Lemin *et al*. 2018). Pinnarendi has 690 mm aar (highly seasonal) and red-earth soils (pH ~6.4) with low fertility. Inter-row pasture comprises grasses *Bothriochloa pertusa, Urochloa mosambicensis, Heteropogon contortus*, *Chloris gayana* and legumes *Chamaecrista rotundifolia*, *Stylosanthes spp*. Grazing by Brahman (*B. indicus*) and Droughtmaster (*B. indicus x B. taurus*) weaner steers was conducted for a minimum of 365 days for three cohorts. Animals were allocated to R or W treatments in even groups by weight and type and remained within treatments for grazing. Cohort 1 animals were rotated between paddocks; stocking was conservative. Cohort 2 animals were rotated between paddocks (overlapping Cohorts 1 and 3); stocking was low due to dry conditions. Cohort 3 animals remained within the same paddocks; stocking was maximised. Animals were weighed at about six weekly intervals (no curfew) and fed molasses (weekly) equivalent to 1 MJME/head/day for habituation to handling. Animals were offered commercial dry and wet season lick blocks comprising 30% urea and 8% phosphorus respectively; with intake monitored. Cohort 3 animals were administered either R or W adapted rumen inoculant (sourced from the DAF Tick Fever Centre).

Cattle readily consumed R (and W) across all cohorts and years. Cooler temperatures and low soil moisture constrained leucaena productivity from about May to October in each year. Psyllids occurred at the site in all years but did not persist in sufficient numbers to cause yield loss. Liveweight, Average Daily Gain (ADG) and stocking rate are shown in Table 1 for each cohort. Average annualised liveweight gain ranged from 202–238 kg and 199–247 kg for R and W respectively. Data for Cohorts 1 and 3 was analysed by an analysis of variance for ADG and end weight. There was no significant difference between R and W for ADG ($P = 0.343$ and $P = 0.371$; Cohort 1 and 3 respectively) or end weight ($P = 0.332$ and $P = 0.416$; Cohort 1 and 3 respectively). No statistical analysis was conducted for Cohort 2 due to a lack of replication.

Table 1. Liveweight, ADG and stocking for three cohorts of steers grazing Redlands and Wondergraze leucaena at Pinnarendi, 2018–2021 (mean ± standard error of mean)

Cohort	No. of days	No. of head	Wondergraze				Redlands			
			Average start weight (kg)	Average end weight (kg)	ADG (kg)	Stocking rate (AE/ha)	Average start weight (kg)	Average end weight (kg)	ADG (kg)	Stocking rate (AE/ha)
1	368	28	232 ± 10	482 ± 11	0.68 ± 0.02	0.40	226 ± 7	465 ± 9	0.65 ± 0.02	0.39
2	372	14	267 ± 20	470 ± 20	0.55 ± 0.02	0.34	257 ± 21	463 ± 26	0.55 ± 0.02	0.33
3	367	42	265 ± 10	501 ± 10	0.64 ± 0.02	0.58	264 ± 10	478 ± 15	0.59 ± 0.03	0.57

AE, adult equivalent (450 kg steer at maintenance).

The trial has demonstrated equivalent liveweight performance for cattle grazing R and W. A productivity advantage from adopting R in psyllid prone environments was not demonstrated due to the absence of significant psyllid populations during grazing. Weight gains were measured at most weighing events over all years for both R and W. This is in contrast to animals grazing native pastures on red-earth soils in similar environments when weight loss is usual during the mid-late dry season due to low quality pasture. Under such conditions annual weight gains of 80–100 kg/head (ADG = 0.22–0.27 kg) at stocking rates of 0.10–0.13 AE/ha are typical (unpubl. data). Establishment and management costs and animal performance data from the trial will better inform producers considering leucaena adoption in north Queensland.

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Effects of adsorbents and probiotics in mitigating simplexin poisoning effects in cattle fed Pimelea

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Pimelea poisoning of cattle occurs only in arid inland Australia and is caused by the toxin, simplexin found in some native Pimelea plant species. Pimelea-affected cattle show distinctive physical symptoms including subcutaneous oedema under the jaw and brisket, diarrhoea and anaemia. Simplexin was thought to be circulated in the bloodstream to exert its toxic effect, but due to its hydrophobic nature the extent of its blood carriage is unknown. Fletcher *et al*. (2014) postulated a possible role of rumen microorganisms adapting to detoxify simplexin in cattle fed Pimelea over a prolonged period of time. Anecdotal reports have suggested cattle supplemented with biochar and bentonite showed resistance towards Pimelea poisoning. In this project, a pen trial (QAFFI/QASP/337/20/DAF) was conducted to determine the efficacy of adsorbents (biochar and bentonite) and a bacterial inoculum for reducing the effects of Pimelea poisoning in steers.

Thirty steers (8 months old) with no previous exposure to Pimelea were assigned to six treatment groups containing five animals per group stratified by weight. Each steer was allocated to individual pens in a randomised block design. The six treatment groups were: (1) Positive control: hay + Pimelea, (2) Negative control: hay only, (3) Non-activated biochar: hay + Pimelea + non-activated biochar, (4) Activated biochar: hay + Pimelea + activated biochar, (5) Bentonite: hay + Pimelea + bentonite, and (6) Inoculum: hay + Pimelea + rumen-derived inoculum. Hay was fed to all steers daily on an *ad lib* basis. Steers in all groups (other than Negative control) were fed Pimelea daily to provide a dose of 5 µg simplexin/kg bw/day, with the dose increased to 7.5 µg simplexin/kg bw/day at Week 9 of feeding. The biochar and bentonite were fed daily at a dose of 0.3 g adsorbent/kg bw/day. The bacterial inoculum was administered orally (200 mL) to steers fortnightly. Pimelea feeding and treatments were stopped at the end of Week 11, with hay fed to all steers until Week 14. The health of steers was monitored and scored daily. Steers were taken to the crush weekly to be weighed and for jugular blood collection. Jugular blood was sampled for haematology and biochemical analyses and for simplexin detection using LC-MS analysis.

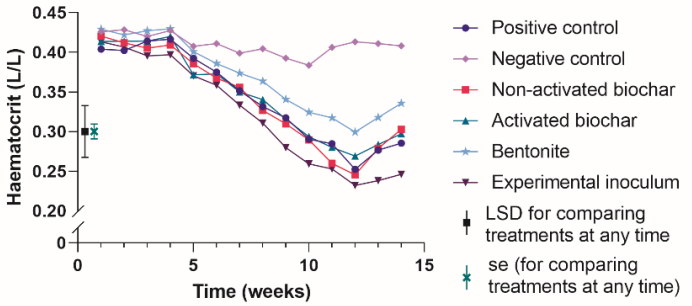

Fig. 1. Blood haematocrit levels measured weekly for all six treatment groups during the feeding trial. Data was presented as adjusted means standardised for the blocks, covariate, group and missing values. LSD, Fisher's protected least significance difference; se, standard error of mean.

All steers fed Pimelea showed signs of Pimelea poisoning with diarrhoea, oedema and increased heart rates observed. Four steers were euthanised with two steers showing adverse effects of Pimelea poisoning while two steers had coincidental physical causes of decline. After Pimelea feeding was ceased, remaining affected steers gradually recovered and were free of any symptoms. For Pimelea dosed animals there was a general trend in decreasing haematocrit (Fig. 1), haemoglobin, packed cell volume, red blood cells and mean corpuscular haemoglobin concentration, with the magnitude of decrease varying between treatments. In all five parameters, the bentonite treatment group showed an increased resistance to the Pimelea impacts compared to other treatment groups. The activated biochar, non-activated biochar and experimental inoculum did not reduce Pimelea poisoning effects in steers and the five parameters from the three treatment groups were similar to the Positive control group. An LC-MS/MS method was developed for simplexin detection in freeze-dried blood with a simplexin limit of detection (LOD) of 3 ng/g in dried blood. However, simplexin in freeze-dried blood from steers fed Pimelea was below the detection limit, despite steers exhibiting characteristic signs of Pimelea poisoning. Overall, the animal trial showed evidence of bentonite-fed steers to be resistant against Pimelea poisoning compared to biochar and inoculum treated steers while simplexin was below the detection limit in freeze-dried blood.

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Biochar supplementation for beef cattle: methane emissions and grazing applications

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Over the past decade, enteric CH_4 production by livestock has been targeted by ruminant nutritionists because of its contribution to anthropogenic greenhouse gases emissions. In recent years, biochar has attracted interest as an additive for ruminants because of its antimethanogenic potential, although *in vivo* results are limited and sometimes contradictory (Schmidt *et al.* 2019). Our objective was to study the effect on CH_4 emissions and rumen fermentation parameters of two types of biochars (at 4 levels) supplemented to beef cattle in controlled feeding conditions (experiment 1) and its applicability under grazing conditions (experiment 2).

Two biochars were selected from previous *in vitro* studies (Durmic *et al.* 2021): Biochar 1 (*Acacia cambagei*, pyrolysis 450°C) and Biochar 2 (*Eucalyptus* spp., pyrolysis 600°C, acidified, 6.6% KNO_3 added). Experiment 1: 12 Droughtmaster steers were offered Rhodes grass hay *ad lib* and randomly allocated to two groups, receiving one of the biochars at four doses + molasses (200 mL/animal.day): Control with 0.0 % dry matter intake (DMI); 0.5 % DMI; 1 % DMI and 2 % DMI. Animals received the control treatment for 14 d with the last 2 d placed into open-circuit respiration chambers to measure CH_4 production (Martinez-Fernandez *et al.* 2016) and rumen fluid was collected for analyses of fermentation parameters. Following the control period each biochar dose was increased to 0.5 % for 14 d with same sampling regime in the final two days. Same procedure was followed for doses at 1 % and 2 % DMI. Experiment 2: the same two biochars were offered daily at a single dose estimated to be 0.5–1% DMI to cattle grazing at Lansdown Research Station (Qld) to study the effect on productivity and CH_4 emissions measured by Greenfeed units (Hammond *et al.* 2016). The dose selected was based on experiment 1 results and the treatments were provided to animals as a voluntary intake to simulate an extensive grazing system. The treated cattle grazed together with a control group (not receiving biochar additive) in the same paddock for 60 days (15 animals per group, animals were auto-drafted daily to treatments). The three groups received the same amount of molasses (2.86 kg group/day). Both experiments were approved by CSIRO Animal Ethics Committee (2020-13 and 21-06). Data was analysed using a general linear model of SPSS (IBM, version 21.0) as a univariate repeated measures for the pen trial and a univariate model for the grazing trial.

A significant ($P < 0.05$) CH_4 reduction was observed with both biochars (8.8-12.9 % reduction, showing a linear and cubic dose-dependent response for biochar 2), with no significant effect on DMI or rumen fermentation parameters in the pen trial (experiment 1, Table 1). In the grazing trial (experiment 2) no significant differences were detected for enteric CH_4 emissions (g/day) or average daily weight gain (ADWG) in cattle supplemented with the biochars compared with the control group.

Table 1. Effects of Biochar 1 and 2 on DMI and CH_4 emissions in steers fed Rhodes grass hay (experiment 1)

		Control	0.5 % DMI	1 % DMI	2 % DMI	SEM	*P*-value
DMI (kg)		7.91	8.08	8.03	7.90	0.13	0.555
CH_4 (g/day)	Biochar 1	189^{a}	176^{bc}	182^{ab}	170^{c}	5.09	0.007
CH_4 (g/kg DMI)		23.9^{a}	21.8^{b}	22.8^{ab}	21.5^{b}	0.40	0.029
DMI (kg)		8.54	8.61	8.65	8.47	0.33	0.706
CH_4 (g/day)	Biochar 2	197^{a}	180^{bc}	188^{b}	170^{c}	6.89	0.001
CH_4 (g/kg DMI)		23.2^{a}	21.0^{c}	21.7^{b}	20.2^{c}	0.86	0.001

Row-wise superscripts indicate different treatment means ($P < 0.05$).

The biochars and doses tested reduced CH_4 emissions (8.8-12.9 % reduction) in cattle under controlled feeding conditions without any detrimental effect on rumen fermentation or DMI. However, under grazing no significant difference in enteric CH_4 emissions or productivity could be detected when the same biochars were supplemented over 60 d. It was concluded that the two biochars, at doses tested here were not suitable to be used as an abatement strategy in grazing cattle. Further research is required to identify biochar types, doses, and delivery methods suitable to achieve sustained CH_4 mitigation for grazing systems. To be viable under grazing conditions, the supplement will require a greater CH_4 reduction potential than reported in the current study under controlled feeding conditions.

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Responding to Climate Challenges in the Northern Downs, Queensland

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The Northern Downs region in Queensland consists of open and undulating grasslands, and is characterised by a hot and dry climate, with a distinct wet season but high variability in inter-annual (year to year) rainfall. Long term projections for this region indicate that beef producers will be impacted by higher average temperatures in all seasons, increased atmospheric CO_2, and an increase in the frequency and intensity of extreme events such as heatwaves and cyclones (Moise *et al.* 2015). Changes to rainfall are unclear, but inter-year variation will remain high. The MLA-funded *Nexus* project aims to explore interactions between profitability, productivity, and sustainability of livestock businesses in a future climate, with this paper focusing on the identification of potential adaptation options.

Our analysis builds on a previous case study developed by the Queensland Department of Agriculture and Fisheries (Bowen *et al.* 2020). We used small-group discussions with local producers and extension staff (n = 12) to understand the most important climate challenges for the Northern Downs region and identify potential adaption options. Adaptation options included approaches that are currently available to land managers, and those that may be developed in the future.

Key climate-related issues prioritised by the group were an increase in woody thickening/encroachment, changes in pasture production, and heat stress in livestock. Potential adaptation options are summarised in Table 1 and will be evaluated using bio-economic modelling in the next stage of the project. Other challenges identified that will need to be managed in conjunction with climate change include a perceived disconnect between government policy and the reality of livestock production, market anxiety, succession planning, digital connectivity, consumer attitudes, and availability of skilled labour. These socio-economic problems are part of a complex mix of factors that beef producers are contending with when operating and making decisions for their businesses.

Table 1. Key climate challenges and adaptation options identified by producer group

Problem	Details	Adaptation options	Challenges
Woody thickening and encroachment	Reduced grazing area, hinders property management, refuge for pest animals, reduced land value	• New methods (e.g. biocontrol) • Valuing woody vegetation as shade for livestock	Lack of viable options – current methods are costly and labour intensive
Changes in pasture production	Difficulties in preparing feed budgets due to highly variable seasons	• Improved forages to fill feed gaps • Adaptive stocking rates • Agistment or purchasing land in other regions	Difficult to find pasture species that will persist in local environment; risky to trial new forages on a commercial scale; markets not always available to sell in to; cost of moving stock; increasing land values make it expensive to acquire additional land
Increased heat stress in livestock	Reduced animal survival, productivity & welfare	• Genetics • Extra water points & shade • Change timing of calving	New genetics not readily accessible; cost of infrastructure

Producers in the Northern Downs region of Queensland already experience many of the problems identified in Table 1, with climate change expected to exacerbate the challenges of beef production in this region. While producers were able to identify potential adaptation options, there are technical, financial, and social barriers to their implementation. Climate challenges need to be considered in the context of other social, economic, and regulatory pressures.

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Does the provision of artificial shade influence the reproductive performance of pregnant beef heifers in the Barkly Tableland, Northern Territory?

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Grazing conditions for many beef herds in northern Australia are harsh, consisting of large distances between water points, high temperatures and humidity during summer months, and substantial areas of relatively treeless grasslands. In regions with largely open grazing plains, such as the Barkly Tableland, grazing animals can be exposed to heat stress events that elsewhere have adversely affected production. The provision of artificial shade has been shown to mitigate some production impacts from heat stress (da Silva et al 2019). This paper presents preliminary results from the 'Reducing calf loss from exposure study', comparing the reproductive performance of two groups of Wagyu with and without shade, with replication achieved by repeating the study in 2 years.

This study utilised two small (56 km^2) paddocks of very similar size and production potential on Avon Downs Station, Barkly tableland. The paddocks were relatively treeless with cracking clay soils supporting productive Mitchell and Flinders grasslands. Each paddock had 7 water points strategically located so that the largest distance from water in either paddock was 4 km. Shadecloth shade shelters (50 m × 25 m in size) were installed within 200 to 500 m of each water point in one of the two trial paddocks. Paddocks were stocked using recommended pasture utilisation rates following an inspection of the pasture biomass on offer at the end of the wet season (April–May). Each year, heifers (predicted to calve between October and December) were selected at the annual pregnancy test muster of a large maiden heifer mob, with individuals randomly allocated to either the paddock with (S) or without (NS) installed shade shelters. Heifers inducted into the study were typically observed for approximately 12 months, from pregnancy diagnosis (August–September) to weaning (June–July). Data capture was supported using crush-side individual animal performance recording software and with each animal individually identifiable by both a NLIS compliant RFID ear tag and a visual management ear tag displaying a unique number. At induction, predicted month of calving, body condition score (BCS) and lactation status was recorded. At the weaning muster, heifers were assessed visually for BCS and lactation status, pregnancy tested and foetal age estimated if pregnant. Liveweight, sex and treatment group were recorded for all calves. Heifers observed as not lactating at the weaning muster were considered to have lost their calf. The participation of a year-cohort in the study concluded at the weaning muster, with the next year-cohort of pregnant heifers allocated to the experimental paddocks shortly afterwards. Differences between treatment groups means for foetal and calf loss (FCL), percent pregnant while lactating (WP) and liveweight of calves at weaning (WW) were compared after employing a generalised linear mixed model with treatment fitted as a main effect and year as a random effect using R and RStudio, version 1.4.113.

The reproductive performance of 144 and 270 heifers was successfully described in 2019/20 and 2020/21 calving seasons, respectively and are presented in Table 1. The provision of artificial shade did not have a large impact on reproductive performance with no discernible difference between treatments for FCL, WP or WW identified ($P > 0.05$; Table 1).

Table 1. Mean (± SE) foetal and calf loss (FCL; %), percent pregnant while lactating (WP; %) and weaning weight (WW; kg) by treatment and year

Year	FCL (%)		WP (%)		WW (kg)	
	NS	S	NS	N	NS	N
2019/20	29.2	28.4	90.2	94.3	175.2	182.8
2020/21	38.1	28.2	91.2	90.9	197.5	195.4
Overall	34.2 ± 3.2[a]	28.3 ± 3.2[a]	90.8 ± 2.4[a]	92.2 ± 2.3[a]	187.1 ± 8.9[a]	188.3 ± 8.9[a]

Means in the same year and outcome that do not share a common superscript letter are significantly different at $P < 0.05$.

These results highlight the devastating impact calf loss is having on the productivity of northern beef businesses. However, the provision of artificial shade near watering points does not appear to be an effective method at consistently reducing its occurrence and did not appear to result in any other production gains. Whilst there are potential animal welfare benefits gained by the provision of artificial shade to open grazing lands, due to the high costs associated with their installation and ongoing maintenance, it is unlikely to be profitable.

Reference

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Usuckled Project: liveweight gain of newborn calves and its association with overall liveweight gain

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To aid investigation of production issues, like calf wasteage, substantial investment has been directed towards the development and validation of remote technologies to provide real-time alerts of key production events, like calving. A modified Taggle™ Calf Alert system (single receiver only) was deployed to alert researchers of calving events to enable assessment of cow and calf behaviour around the time of calving in the 'uSuckled' project. This paper describes the observed birthweights and pre-weaning average daily gain of progeny monitored during the study.

The study was conducted at the Katherine Research Station (Katherine, Northern Territory) between October 2021 and February 2022. At approximately one month from expected calving (assuming a mean gestation length of 290 days) 24 Brahman heifers confirmed pregnant from fixed-time artificial insemination were mustered to cattle yards and were equipped with intra-vaginal Calf Alert transmitters. The KoolCollect crush-side individual animal data recording software was used to record the unique ID of each transmitter, as well as liveweight, body condition score and lactation status. An in-field Taggle™ receiver was erected within 1.5km of the study paddock and powered by a 110 Ah per day solar system with 660Ah battery storage. TerraCipher Pty Ltd were engaged to access and analyse data in real time with calving alerts sent via text and email. From two weeks prior to the expected date of calving, the heifers were visually observed twice per day to identify calving events.

When practical after birth, usually within 12–24 h of birth, calves were captured, individually identified using visual tags and data recorded for liveweight, sex and notes on their general appearance. Once a fortnight, all study animals (cows and calves) were mustered to the cattle yards and measured for liveweight. The average daily gain for calves were calculated by linear regression based on observations of liveweight on age (days). Calves were categorised as 'HIGH' or 'LOW' growth based on being either having greater than or less than the median value for observed growth between birth until their first liveweight measurement (typically 7–10 days), respectively.

Substantial challenges were incurred with remotely detecting calving events in this study and meant that calving events were detected by physical observation.

Overall, the birthweight averaged 26.5 ± 1.05 kg and was, on average, 3.7 ± 2.0 kg greater for males, than females, which trended towards statistical significance ($P = 0.06$). The liveweight gain of newborns (from birth to 7–10 days) averaged 0.56 ± 0.09 kg.day^{-1} and was not found to be associated with either sex ($P = 0.35$) or birthweight ($P = 0.38$). However, a strong positive association existed for overall liveweight gain ($P < 0.001$) with the half of the cohort that had HIGH growth from birth to day 7–10 of life displaying 0.18 ± 0.03 kg.day^{-1} higher growth than the LOW group (0.93 vs 0.75 kg.day^{-1}, respectively).

These findings are consistent with published reports by Muller (2017) and illustrates the importance and ongoing effect of neonatal management. The reduced growth between birth and day 7–10 of life displayed by some calves is potentially partially explained by suboptimal milk quality and intake, thought to be largely associated with the high nutritional requirements of first-lactation cows.

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Understanding the incidence of dystocia related death in ewes: a key to unlocking ewe survival

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Dystocia is defined as a difficult birth, or birth process due to a long, unassisted parturition (lambing) requiring assistance (Arthur *et al.* 1982). Dystocia can occur due to maternal factors or foetal factors (Jacobson *et al*. 2020) or both in the case of fetopelvic disproportion with inadequate ewe pelvis size being a maternal factor and an oversized foetus or foetuses being a foetal factor.

The foetal origin of dystocia relates to malpresentations, congenital deformities and foetal disease and death while maternal factors include uterine inertia, incomplete cervical dilation (ring womb), uterine torsion, foetal-pelvic disproportion (Arthur *et al.* 1982), vaginal prolapse and inguinal hernia (Jacobson *et al*. 2020). If left unassisted dystocia will directly compromise ewe and lamb survival (Arnold and Morgan 1985). Dystocia-related mortality may be attributed to haemorrhage, trauma and septicaemia (Mavrogianni and Brozos 2008).

There is little published data on incidence of dystocia related death in Australian ewes (Jacobson *et al*. 2020). In the study by Harris and Nowara (1995), dystocia was recorded to have caused mortality in 18% of the recorded dead ewes which were 3 years and older and in 6% of ewes that were rising 1 year olds.

The aim of this research is to determine the incidence of dystocia related deaths in commercial non-merino ewes in Australia during the lambing period.

Over 2 lambing seasons (in 2019 and 2020), 50 host producers were selected to record the number and suspected causes of ewe deaths that occurred from the time ewes were placed in lambing paddocks until lamb marking. Concurrently project veterinarians conducted post-mortem examinations on any ewes that has died on the property within 48 h of three scheduled veterinary visits on each property.

According to producers, obvious dystocia (recorded as 'stuck lamb/s) was the cause of death in in 33% (95% CI: 27%, 39%) and 28% (95% CI: 22%, 34%) of ewes over the lambing period in 2019 and 2020 respectively. This was mirrored in the post-mortem examinations where in 2019 41% cases (95% CI: 29%, 49%) and in 2020 29% cases (95% CI: 20%, 36%) were diagnosed with dystocia. Of the ewes that underwent a post-mortem exam and that were diagnosed with dystocia, the most common type of dystocia was malpresentation (58%), followed by foetal size (15%) and uterine inertia with failure to progress labour for unknown reason (13%). Just under half of the cases of dystocia identified using post-mortem examinations had no obvious external signs of dystocia.

Dystocia related ewe deaths have been underreported in Australian commercial ewe flocks. Further research into the role that Australian Sheep Breeding Values (ASBVs) such as lamb birth weight (BWT) and lambing ease (LE) play in reducing dystocia related ewe death is warranted.

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Co-benefits of trees on farms in southern Australia: a database to support tree planting decisions

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Integrating trees into farming systems can increase carbon stocks while improving farm productivity and resilience. However, multiple factors deter farmers from planting trees. These include the difficulty in accessing relevant and reliable information on the costs and benefits of trees and incorporating it into the decision-making process. To address this gap, a database was developed to support on-farm decisions and provide a repository of information regarding co-benefits of trees on farms. The literature reviewed consistently supports the benefits of shelter for lamb and shorn sheep survival as well as animal welfare. Tree planting impacts on productivity metrics such as carrying capacity, liveweight gain, and wool production were highly variable and influenced by landscape context, tree density, planting configuration and tree age. This highlights the importance of planting design on the impacts of integrating trees into farm systems.

The database included literature from studies in New Zealand and the temperate sub-humid, temperate cool season wet, and Mediterranean zones of Australia. It was populated using published information from peer-reviewed sources and other literature. Only articles that included data on impacts of trees on farm were included.

The initial version of the database includes 90 articles with 40.4% reporting experimental data and 34.8% reporting farm data. Most publications are journal articles (73.0%) followed by factsheets (7.9%), books (6.7%) and conference proceedings (6.7%). Information on farm productivity impacts comprises 53.4% of the data entries. Table 1 provides the information from the database on impacts of shelterbelts on sheep mortality. Information on agroforestry systems show that increasing density of trees has increasingly large impacts on livestock production. Impacts on livestock production are also influenced by the configuration of agroforestry plantings. Carbon dioxide sequestration rates were estimated in 16.6% of entries. These range from 3.6–35.1 t CO2e/ha/year, with the range reflecting variation between species and growing conditions. Other benefits identified in the literature include biodiversity (11.9%), water quality and availability (10.9%), and soil factors such as erosion, salinity, and amounts of carbon (27.5%). Incorporation of farmer observations allowed for animal welfare information (3.1%) such as biosecurity benefits.

Table 1. Reported impacts of shelterbelts on mortality in sheep (Meyer *et al.* 2022)

Animal class	Data type	State	Reduction in mortality with shelter
Lambs (marking rate)	Farm data	Tasmania	4.8%
Lambing (percentage)	Farmer observation	Victoria	Up to 11%
Lambs (mortality rate)	Unpublished data	Victoria	36%
Lambs (mortality rate)	Experiment	Victoria	58.7%
Shorn sheep	Farmer observation	Victoria	Unspecified reduction
Shorn sheep	Farm data	South Australia	Variable, shelter characteristics matter
Shorn sheep	Farmer observation	New South Wales	Nearly 0 losses to weather

This database will be used for more detailed analysis of the relationships between tree cover or configuration and farm productivity (e.g. liveweight gain, wool or milk yields) and other co-benefits. It will also aid in identifying research gaps. It will support a decision framework currently under development that will allow easy access to information on the factors farmers identify as critical to their tree planting decisions.

Reference

Meyer R *et al.* (2022) Database of Tree Co-benefits and Disadvantages to Livestock Farms. Excel version.

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The effect of metabolic state on parturition duration in twin-bearing Merino ewes

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In Australia, dystocia contributes to approximately 53% and 35% of lamb and ewe deaths annually, making it a significant economic and welfare concern (Bruce *et al*. 2021). Recent research suggests that ewe nutrition may be linked to cases of dystocia (Jacobson *et al.* 2020). Improving ewe nutrition in late gestation can improve ewe condition and lamb survival through improved milk production (Thompson *et al.* 2011). In contrast, poor nutrition has the opposite effect and causes increasing levels of ketone bodies that can lead to metabolic disease, and, in Chios-cross ewes, increased incidence of dystocia (Barbagianni, *et al.* 2015). The effect of ewe metabolic state around the time of lambing may affect parturition duration and the incidence of dystocia in Merino ewes. It was hypothesised that ewes with lower glucose and higher ketone bodies will have a prolonged parturition duration.

This study was conducted at Turretfield Research Centre, Rosedale, SA and was approved by the Primary Industry and Regions South Australia Animal Ethics Committee (#06/21). At day 100 of gestation 18 twin-bearing ewes were placed into the following treatments: 1.0 Maintenance, ewes fed a diet at maintenance energy levels (n = 9), or, 1.25 Maintenance, ewes fed a diet 25% above maintenance energy level (n = 9). Ewes were housed indoors in individual pens under 24/7 video surveillance and diets consisted of a commercial ewe and lamb pellet, barley, peas and oaten hay. Ewes were weighed and body condition scored (BCS) weekly from day 100 of gestation until parturition. A 10 mL blood sample was collected on days 130 and 140 of gestation, 1 day pre-partum, pre-partum (first visible sign of parturition) and post-partum (30 min after the second lamb was born). Ewe metabolic state parameters consisted of blood glucose and ketone bodies (Accu-Chek Performa, Sydney, Australia) and serum calcium, cholesterol, phosphate, beta hydroxy butyrate, non-esterified fatty acids and magnesium (Konelab20Xti). At birth, lamb meconium stain score was recorded, and a blood sample was collected to measure blood gasses via EPOC machine (Epocal Inc.). Parturition length (from visible amniotic sac/strong contractions until expulsion of lamb B) and difficulty score was also recorded. At 4 h post-partum lambs were weighed, and body morphology was recorded. Data were analysed using a General Linear Model (scale variables) or a multinominal logistic regression (ordinal variables) (IBM SPSS Statistics for Windows, v26.0; Armonk, NY, USA). Ewe blood measures, parturition duration, liveweight, BCS and parturition difficulty score were analysed with ewe as the unit and lamb viability was measured with lamb as the unit. A linear regression analysis irrespective of treatment was performed on all measures against parturition length.

There was no significant effect of treatment on any ewe or lamb measures ($P > 0.05$), however, parturition length tended to be longer and pre- and post-partum blood glucose tended to be lower in 1.25 Maintenance compared to 1.0 Maintenance (Table 1). There were also no significant relationships between parturition length and other measures, except for a weak positive relationship with lamb birthweight ($P = 0.010$, $R^2 = 0.147$).

Table 1. Effect of feeding twin-bearing Merino ewes a 1.0 and 1.25 maintenance feed level from day 100 of gestation on parturition length, and ewe blood glucose pre- and post-partum[A]

	1.0 Maintenance	1.25 Maintenance	*P*-value
Parturition length (min)	73.1 ± 1.2^{x}	107.6 ± 1.2^{y}	0.097
Day –1 prepartum blood glucose (mmol/L)	3.2 ± 0.4	3.4 ± 0.5	0.817
Pre-partum blood glucose (mmol/L)	7.8 ± 0.8^{x}	5.4 ± 0.7^{y}	0.081
Post-partum blood glucose (mmol/L)	11.0 ± 0.8^{x}	8.5 ± 0.8^{y}	0.079

[A]Values presented as means ± standard error of the mean. Different superscripts within a row indicate $P < 0.1$.

This study demonstrated that increasing ewe energy availability does not significantly alter the metabolic state or parturition duration compared to maintenance feed levels. Additionally, metabolic state did not have a significant relationship with parturition duration, irrespective of treatment, refuting the hypothesis, however, it is important to note that all ewes (except one) were healthy and perhaps inducing metabolic disease will create larger variations in metabolic state as opposed to a higher plane of nutrition. Further studies with greater numbers are required to validate the trends seen in parturition length and blood glucose pre- and post-partum.

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Beneficial responses to a novel probiotic in feedlot lambs

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Bacillus amyloliquefaciens strain H57 (H57) is a naturally occurring bacterial probiotic originally isolated from lucerne *(Medicago sativa)* leaves. Short-term feeding experiments indicate that feedlot pellets inoculated with H57 are preferred by cattle, possibly by acting as a feed preservative to reduce the rate of microbial spoilage during storage (Ngo *et al*. 2021*a*). In addition, inoculation of ryegrass-clover hay or palm kernel-sorghum based pellets with H57 increases the organic matter digestibility, feed intake and liveweight gain of pregnant ewes (Norton *et al*. 2008; Le *et al*. 2017). We hypothesised that similar effects would be observed in lambs fed H57 inoculated feedlot pellets during fattening, after pellets were stored for up to 4 months prior to feeding.

After a 17-d adaptation period, 4 pelleted treatments (920 g dry matter (DM)/kg, 150 g crude protein (CP), 253 g neutral detergent fibre (NDF) and 13.5 MJ ME/kg DM) with a basal allocation of cereal chaff (915 g DM/kg, 61 g CP, 572 g NDF and 9.1 MJ ME/kg DM), were fed to 48 Dorper cross wether lambs for 68 -d in pens at the Queensland Animal Science Precinct, Gatton. Lambs were initially blocked on liveweight and randomly allocated to pens, 2 lambs per pen, such that each pen contained approximately the same starting total liveweight. The design was a randomised complete block (2 × 2 factorial) with 6 blocks and pen as the experimental unit. There were two storage conditions (cold and ambient), and two probiotic addition to pellets; Control [–H57] and +H57. Ambient pellets were stored in an enclosed shed whilst Cold pellets were stored at 4°C for 4 months. The +H57 treatments had H57 spores added at the point of pellet manufacturing at 2×10^6 cfu/g pellet as fed (92% DM) and immediately placed into storage. The daily pellet offering per pen was gradually increased from 1.6 kg, as fed, at the commencement of treatments until *ad libitum* intakes were reached after approximately 14 d. Chaff was allocated at 0.6% LW per pen daily (DM basis). Total faecal output was collected from each lamb into nylon stockings over five consecutive days between d 22 and d 27 to estimate digestibility of the diet consumed in each pen. Rumen fluid was collected from each lamb at the conclusion of the faecal collection period and the pH measured. Estimates of mean DM intake, diet digestibility and rumen pH during the faecal collection period were analysed using a mixed model ANOVA.

Lambs fed H57 inoculated pellets consumed less chaff than lambs fed control pellets ($P < 0.05$; Table 1). However, neither storage or probiotic addition altered pellet or total DM intake during the period of total faecal collection. The addition of H57 to lamb feedlot pellets increased DM and NDF digestibility, and rumen pH ($P < 0.05$) regardless of pellet storage conditions. There were no significant interactions between storage conditions and probiotic addition for any of the measurements.

Table 1. Mean dry matter intakes, diet digestibility and rumen pH of lambs fed feedlot pellets with (+H57) and without (–H57) probiotic and chaff[A]

	–H57		+H57		s.e.m	*P*-value		
	Ambient	Cold	Ambient	Cold		Storage	Probiotic	Storage × Probiotic
Intake (g/day)								
Pellets	2942	2801	2817	2844	76.1	0.729	0.801	0.609
Chaff	369	389	301	334	15.1	0.356	0.045	0.829
Total	3310	3191	3117	3178	74.6	0.852	0.52	0.572
Digestibility (%)								
DM	65.0	64.8	67.4	66.4	0.45	0.521	0.031	0.685
NDF	47.0	47.7	54.9	51.4	1.29	0.552	0.024	0.386
Rumen pH								
pH	6.35	6.48	6.72	6.59	0.060	0.954	0.036	0.248

[A]Values are least-square means, standard error of the mean (s.e.m) and *P*-values arising from linear mixed effects modelling.

Lambs fed H57 inoculated pellets consumed a diet with a lower proportion of chaff, which likely contributed to the increased DM and NDF digestibility. Despite consuming a lower fibre diet, lambs consuming H57 treated pellets had a higher rumen pH, which agrees with previous studies in ewes and steers fed H57 inoculated pellets (Le *et al*. 2017; Ngo *et al*. 2021*b*). It is plausible that the control lambs selected more chaff to mitigate the effects of lower rumen pH. This study indicates that inoculation of pellets with H57 may increase the productivity and improve health of lambs by increasing diet digestibility and rumen pH, which would be beneficial to the sheep feedlot industry.

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Hypersensitive immune response in the development of buffalo fly lesions in north Australian cattle

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Buffalo flies (BF) (*Haematobia irritans exigua*) are major ectoparasites of cattle causing economic and welfare impacts in north Australian herds. They are extending their range southward. Skin lesions associated with BF feeding are manifested as focal dermatitis or ulcerated areas most commonly on the medial canthus of the eye, along the lateral and ventral neck, and on the abdomen. Lesion pathogenesis has been attributed to a filarial nematode, *Stephanofilaria* sp., transmitted by BF (Johnson *et al*. 1981), but recent findings have shown that infection with *Stephanofilaria* is not necessary for the development of BF lesions, and this together with the observed poor correlation between BF numbers and lesion development, suggests that other factors contribute to development of lesions (Naseem *et al*, unpubl. data). This study aimed to identify the role of cattle immune response in the pathogenesis of buffalo fly lesions.

Towards this objective, 17 Brangus steers approximately 3 years of age were phenotyped for lesion susceptibility over two BF seasons. The steers were classed as lesion resistant (LR) (no skin lesions; $n = 10$) and lesion susceptible (LS) with high lesion scores ($n = 7$). Each animal was injected intradermally on the upper flank with 0.1 mL of different concentrations of BF soluble antigens (100, 10 and 1 µg/0.1 mL), *Onchocerca gibsoni* (ON) and house fly (Md) antigens (100 and 10 µg/0.1 mL). Wheal area was measured at each injection site 1 h after injection and skin thickness, adjusted for pre-injection skin thickness of each animal, was measured at 24, 48 and 72 h following injection. In addition, to examine the immune changes at the tissue level, skin biopsies were collected from the BF injection sites (100 µg/0.1 mL) of five LS steers at 72 h post-injection and histological examination conducted.

Lesion susceptible cattle had a significantly stronger immediate hypersensitive response to 100 and 1 µg of BF antigen, as measured by wheal area at one-hour post-injection, and significantly greater skin thickness to all 3 concentrations of BF antigens at 24, 48 and 72 h (Table 1). Although the difference at 1 h was not statistically significant for the 10 µg/mL BF antigen concentration ($P = 0.05$), skin thickness was greater in the LS cattle ($P = 0.066$). There was no difference between LS and LR cattle with either ON or Md antigens at 1 h and no difference in skin thickness to ON antigens at any of the later times. Skin thickness in response to Md antigens was greater in the LS than LR cattle at the later times, although the size of the wheals was smaller than with the BF antigens. This was thought to be due to the presence of cross-reacting antigens in the BF and Md extracts, probably unsurprising given the relatively close phylogenetic relationship between BF and Md. At 48–72 h post-injection, superficial epidermal disruption was noted at the BF injection site in LS animals and there was development of a dry serous crust over the injection site. Histology of skin sections at 72 h post-injection revealed destruction of the epidermis, hair follicles and sweat glands, and a severe inflammatory reaction comprised of mainly eosinophils and neutrophils with plasma cells and lymphocytes also commonly observed in response to BF antigens.

Table 1. Wheal area (mm^2) at 1 h and skin thickness (mm) at 4 days following intradermal injection with buffalo fly (BF), *Onchocerca* (ON) and house fly (Md) antigens in lesion susceptible (LS) and resistant (LR) cattle

	Wheal area 1 h after injection (mm^2)							Skin thickness (mm) at 4 days after injection						
Antigen	BF1	BF2	BF3	ON1	ON2	Md1	Md2	BF1	BF2	BF3	ON1	ON2	Md1	Md2
LS	25.6	14.1	9.9	20.1	16.0	19.3	13.6	20.6	19.3	17.9	19.3	17.9	17.3	15.4
LR	15.4	10.6	6.2	22.1	13.9	19.3	11.9	15.7	14.4	15.2	17.8	16.5	14.9	13.1
P-value	*	NS	**	NS	NS	NS	NS	***	***	**	NS	NS	*	*

BF1 = 100 µg, BF2 = 10 µg, BF3 = 1 µg, ON1 = 100 µg, ON2 = 10 µg, Md1 = 100 µg, Md2 = 10 µg.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; NS, non-significant.

The wheal and flare response at 1 h post-injection indicates a BF-specific Type-I hypersensitivity reaction in LS animals. The skinfold thickness responses, gross and histological changes could either be due to late phase immediate hypersensitivity response or a delayed Type-IV hypersensitivity, causing acute to sub-acute necrotising neutrophilic eosinophilic dermatitis. These findings suggest that differences in hypersensitive response to BF antigens may underlie differences among cattle in susceptibility to BF lesion development. Further characterisation of this response may aid in the identification of biomarkers for selecting lesion resistant cattle.

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Effects of microbial additives on ruminal dry matter degradability of avocado (*Persia Americana*) pulp silage

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Shortages of feed resources affect livestock production under emerging livestock farmers in South Africa. This can be overcome by the utilisation of agro-industrial by-products, which contain valuable nutrients (De Evan *et al*. 2019). Avocado (*Persia Americana*) pulp (AP) is a by-product from oil extraction in avocados and contains valuable nutrients which can be beneficial to animal nutrition (Skenjana *et al*. 2006). However, the high moisture (700 g/kg DM) makes it difficult to use AP in animal nutrition; hence it should be preserved for future use. The present study evaluated the effects of microbial inoculation on ruminal DM degradation of AP silage. The silage was produced by mixing 800 g/kg AP, 150 g grape pomace (GP)/kg and 50 g sugarcane molasses/kg fresh material (FM). The mixture was treated with (1) no additive (control), (2) EM Silage (EMS; EMNZ, Christchurch New Zealand) or (3) Sil-All 4x4 Water Soluble (Sil; Lallemand Animal Nutrition, France) and ensiled in 1.5 L anaerobic jars for 90 days. After 90 days of ensiling, silage samples were collected, dried, and grounded to pass a 1 mm sieve. For the silage DM degradability study, three rumen cannulated Holstein cows were used. Triplicate samples of each treatment were subsampled, placed in polyester bags, and incubated simultaneously in the ventral rumen of each cow for 2, 4, 8, 16, 24, or 48 h.

Table 1. Effects of treatment on the fermentation characteristics and the degradability of dry matter in ensiled avocado mixture (*n* = 3)

Parameter	Treatment			SEM	*P*-value
	Control	EMS	Sil		
Fermentation characteristics					
WSC (g/kg DM)	17.9^{c}	38.0^{b}	50.4^{a}	0.695	0.001
LAB (log^{10} CFU/kg)	1.73^{c}	7.63^{a}	3.33^{b}	0.149	0.001
LA (g/kg DM)	40.7^{b}	48.6^{a}	46.6^{a}	0.63	0.001
Degradability fraction					
a	33.4^{b}	37.3^{a}	34.4^{b}	0.33	0.004
b	34.0	36.7	34.9	3.12	0.838
c	0.07^{b}	0.03^{c}	0.09^{a}	0.01	0.001
PD	67.9	73.9	69.3	3.06	0.358
ED (%)	57.2^{b}	49.3^{c}	62.1^{a}	0.97	0.003

WSC = water-soluble carbohydrates; LAB = lactic acid bacteria; CFU = colony forming unit; LA = lactic acid; a = soluble fraction; b = potentially degradable fraction; c = degradation rate constant of the b fraction; PD = extent of degradation (a + b); ED = effective degradability % (outflow rate = 0.05). Treatments: EMS = EM Silage; Sil = Sil-All.

Microbial inoculation of either EM Silage or and Sil-All 4 × 4 additives to the AP silage increased lactic acid bacteria population, which subsequently increased residual fermentation substrate and lactic acid content (Table 1). Potential degradable fraction and the extent of degradation were similar among the silage treatments. However, the EMS treatment had higher soluble fractions and lower degradation rate of DM compared to other treatments. The Sil inoculation improved the effective degradation of silage DM compared to other treatments. Microbial inoculation improved the quality of AP silage and further work to test this silage on growth performance of ruminants is needed.

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Long term performance of different cattle stocking strategies in a variable climate

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In the extensive beef industry of northern Australia, failure to manage for rainfall variability such as by applying heavy stocking rates and/or not matching animal numbers to feed availability, frequently results in land degradation and economic loss. While sustainable management strategies such as stocking at long-term carrying capacity (LTCC) exist, adoption rates are often low due to perceived unprofitability. One important factor limiting adoption is the lack of empirical evidence showing the relative economic, production and environmental benefits of recommended strategies. To address this issue, a large (1040 ha) grazing trial was established in 1997 near Charters Towers, Queensland, to test the relative performance of different stocking strategies.

The study area is an open *Eucalyptus-Acacia* savanna, dominated by native grasses; mean annual precipitation is 640 mm. Five strategies were tested: a heavy stocking rate (HSR) stocked at 4 ha/AE (animal equivalent), a moderate stocking rate (MSR) without wet season spelling stocked at the long term carrying capacity of 8–10 ha/AE, a moderate stocking rate at LTCC with wet season spelling (R/Spell) and Flexible stocking (Flex) with or without spelling (+/- Spell). Strategies were replicated twice (O'Reagain *et al.* 2009). Paddocks were stocked with Brahman steers, managed following industry best practice. Cattle were weighed at the start and end of each grazing year (May), gross margins (GM) calculated as product value less costs (O'Reagain *et al.* 2011) and the density of 3P (productive, palatable, perennial) grasses recorded on permanent monitoring sites. Ethics approval was granted by the Department of Agriculture and Fisheries Animal Ethics Committee (SA 2019/06/691).

Rainfall varied markedly (246–1223 mm) over the 24-year trial period, with two distinct wet and dry cycles: 2014/15 (246 mm) was the fourth driest season on record, with on-going drought conditions persisting into the present year. Average annual liveweight gain (LWG) per head over the 24 years was highest in the MSR, R/Spell and Flexible strategies but lowest in the HSR due to reduced feed availability and generally lower diet quality. Conversely, total LWG per ha was highest in the HSR but this was only achieved with expensive drought feeding in seven of the 24 years of the trial (Table 1). Average GM/ha in the HSR was consequently only about half ($7/ha) that of the other strategies ($13/ha).

Table 1. Average annual liveweight gain (LWG) per head (hd), LWG per hectare (ha), gross margin (GM) per hectare and the number of years drought feeding was needed in five treatments over 24 years at the Wambiana grazing trial. The density of 3P grasses in 2021 is also shown. See text for treatment abbreviations

Treatment	LWG/hd (kg)	LWG/ha (kg)	Years drought fed	GM/ha ($)	3P density (tussocks/m-2)
Flex	115	15	1	$13	1.3
Flex+Spell	115	16	1	$13	3.7
HSR	100	19	7	$7	0.5
MSR	117	14	1	$13	2.1
R/Spell	116	15	1	$13	2.4

Heavy stocking resulted in a major decline in pasture condition in terms of the density of 3P species relative to the other treatments. This not only shows the deleterious effects of heavy stocking in this variable environment but also shows that adopting basic principles of good management at least partly ameliorated the effects of the recent severe drought relative to heavy stocking. After 24 years it is nevertheless surprising that the differences in pasture condition between the remaining four treatments are relatively small, possibly reflecting the ongoing, 8-year dry period. However, the results also indicate that constant stocking even at LTCC without reducing stocking rates in dry years will also cause a decline in pasture condition in the longer term. Evidence from this work and other trials also highlights the importance of wet season spelling.

In conclusion, this work shows that all things being equal, heavier stocking rates are likely to be both unsustainable and extremely unprofitable in the longer term. (O'Reagain *et al.* 2018). The results and our experience managing the trial also show that risk-averse flexible stocking around long-term carrying capacity coupled with wet season spelling, is likely to be the most profitable and sustainable strategy for managing climate variability.

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Improving Lao goat production when resources are limited

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Lao People's Democratic Republic (Lao PDR) is a small and developing nation in South-east Asia. Agriculture is its lifeblood, employing 61% of the labour force in 2019, compared to 2.6% in Australia (The World Bank 2021). Small family farms are predominant, relying on rice and crop cultivation to feed the household and generate surplus for income. Livestock are essential for providing manure, consuming non-edible plants and household waste, and serving as a bank account, to be sold when cash is needed. While these systems are vital for human survival, as a tool for household economic growth, there is room for improvement. Goats are gaining popularity among Lao farmers due to their strong export potential. Neighbouring Vietnam is a major importer of Lao goats which receive a price premium of 30% over Vietnamese crossbred goats and Lao farmers keep approximately 70% of the slaughter value (Gray *et al.* 2019). The objective of this study was to assess the current level of inputs to understand the scope to improve goat production.

A structured survey was conducted of 70 smallholder farmers raising goats in the main goat raising province of Savannakhet in central Lao PDR and was approved by University of New England Human Ethics Committee (HE19-218). The survey was conducted in the local language, responses were recorded using mobile acquired data software CommCare® (Dimagi Ltd. Cambridge, MA, USA), and descriptive statistics were generated.

Farm capital was limited, with a low annual income (AU$1558/year, range = AU$249–6981), a dependence on family labour, and participation in a diverse range of enterprises to ensure household resilience to shocks. This meant there would be trade-offs to high-input investments in goat raising. Farmers reported limited access to animal health services and most relied on neighbours (67%) and family (57%) for information. Farmers had reasonable access to water and land (3.6 ha, range = 0–20 ha). Most farmers (64%) depended completely on free grazing of communal land for goat nutrition and grazed goats for 6 h/day in the wet season and 8 h/day in the dry season. This was predominantly unsupervised. This illuminated increasing grazing duration as a possible low risk intervention to boost nutrition. Uncontrolled breeding resulted in year-round kidding which coincided with low nutrition availability for goats in the late dry and early and late wet seasons (Fig. 1). Increased cropping activity likely reduced grazing duration and nutrition available for goats in the late wet season. Growing forages utilising available land with strategic feeding and/or fodder conservation were recommended.

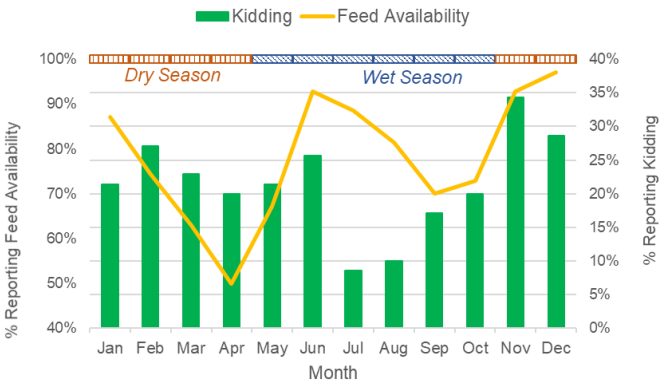

Fig. 1. Proportion of farmers (n = 70) reporting month of kidding compared to the proportion reporting months when there were no goat feed shortages (feed availability) in Savannakhet Province, Lao PDR.

Most farmers viewed disease as the main constraint to production, particularly facial lesions (most likely Orf; 87%) and diarrhoea (57%). Disease management was reactive and unregulated, with 61% of farmers responding by opting for drugs to treat illness, and when asked how they obtained them, 74% purchased them themselves from stores. Increasing farmer disease knowledge through participatory training sessions and explanation of low-cost, accessible and practical treatments are being implemented to directly empower farmers as animal health services are limited. Improving goat house hygiene is one of the low-input preventive strategies that are also being pursued.

These data reflect a low-input system with limited capital. A project has commenced optimising current inputs to maximise productivity outputs while maintaining a low-input system. Social and lifestyle benefits are also being monitored as they are required to motivate households to adopt new management strategies when resources are limited.

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Genetic variation in cow body composition is relatively independent of yearling composition

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At the start of the Beef CRC Maternal Productivity Project, commercial beef breeders raised concerns that genetic selection programs were focusing too heavily on feedlot and carcass traits with a negative weighting on fat depth to increase lean meat yield, and cows were becoming too lean as a result. There was concern that this would lead to a decline in maternal productivity, especially during times of feed shortage (Lee *et al.* 2018; Pitchford *et al.* 2018). Thus, the question to be addressed in this paper is how much genetic variation is there in cow body composition independent of genetic variation in yearling composition? The focus herein is on genetic and not total phenotypic variation.

A genetic covariance matrix was formed using 78 covariances reported by Hickson and Pitchford (2021) from 2641 cows. There were 12 traits including five yearling heifer traits [Weight, Eye Muscle Area (EMA), P8 and Rib fat depth, and Intramuscular fat percent (IMF)] and seven cow traits measured at time of weaning second calf [Weight, EMA, P8, Rib, IMF, Height and body condition score (BCS, 1–5)]. The covariance matrix was not positive definite and so was bent using nearPD in the Matrix package v1.2-17 within R originally developed Jens Oehlschlaegel (https://github.com/joehl) using the algorithm of Higham (2002). The covariance matrix is presented with X representing the five yearling measures and Y representing the seven mature cow measures. The method of calculating conditional cow genetic covariances is:

$$C_{X,Y} = \begin{bmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{bmatrix}$$

$$C_{Y|X} = \Sigma_{22} - \Sigma_{21}\Sigma_{11}^{-1}\Sigma_{12}$$

Just under half (>37%) of the variation in cow weight, height and fat depth was independent of variation in the yearling traits (Table 1). Surprisingly, the least variation was for height which was not one of the yearling traits included in the conditional calculation. Almost two-thirds (61%) of the genetic variation in cow muscle and over three quarters of the genetic variation in BCS and intramuscular fat was independent of variation in yearling traits. Genetic variation in cow BCS is more likely associated with genetic variation in lactation performance and other factors such as time of calving. With the exception of height, genetic variation in all cow traits conditional on yearling traits were extremely highly correlated with each other. This suggests that ultrasound measures of cow condition should not be necessary and that recording weight and/or BCS is sufficient, as aligned with BREEDPLAN genetic evaluation (Graser *et al.* 2005).

Table 1. Genetic variation and correlations between mature cow traits from bent matrix (below diagonal) and conditional on yearling traits (above diagonal)

	Weight	EMA	P8 fat	Rib fat	IMF	Height	BCS
Weight (kg)		1.00	1.00	0.97	0.93	0.56	0.89
EMA (cm^2)	0.75		1.00	0.95	0.92	0.49	0.91
P8 fat (mm)	0.55	0.61		0.95	0.91	0.50	0.91
Rib fat (mm)	0.54	0.60	0.89		0.88	0.71	0.82
IMF (%)	0.26	0.47	0.60	0.59		0.62	0.77
Height (mm)	0.79	0.37	0.17	0.26	0.09		0.26
BCS	0.62	0.75	0.86	0.81	0.60	0.14	
Initial Genetic SD	38.1	3.93	2.52	1.78	0.88	24.9	0.21
Cond. Gen. SD	23.8	3.06	1.64	1.29	0.80	15.2	0.19
Variance remaining	39%	61%	42%	53%	81%	37%	75%

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An observational study to determine changes in nutrient concentrations in perennial ryegrass, lucerne and chicory forages from winter to summer

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Research into global warming and increased climate variability show the potential threat for food security in coming decades. Pasture and animal production systems must evolve to manage a more variable climate. A key feature of future climates is an expected earlier cessation of pasture growth in spring (Cullen *et al*. 2009), resulting in longer periods where animals will need to consume senesced pasture of lower nutrient density than required for maintenance and production. More frequent and intense heatwaves in summer and autumn is expected to continue and will further negatively impact nutrient concentrations of some pasture species. As such, ruminant animal production in many parts of the world including southern Australia faces the challenge of dry paddock feed of low nutrient concentration and energy density. Forage feeds containing low nutrient concentration (e.g. lipids, crude protein, vitamins) not only minimise animal production potential (Burnett *et al*. 2012) but also can lead to greater enteric methane emissions. This is due to elevated production of hydrogen in the rumen associated with microbial fermentation of carbohydrates, resulting in a waste of dietary energy. Use of forages containing vitamins and lipids would be an option to improve both animal performance and production of milk and meat, while reducing enteric methane emissions and improving dietary energy use for production.

There is a need to assess the resilience of forage species to maintain lipid and vitamin concentrations over summer and the identification of suitable diets to feed ruminants during dry seasons so that meat and milk production are not compromised. This study was conducted as a proof of concept during 2020–2021, with vegetative components of three forages: a grass (perennial ryegrass), a legume (lucerne) and a herb (chicory) collected from the Hamilton SmartFarm, Agriculture Victoria Research in three successive seasons, namely winter (July 2020), spring (October 2020) and summer (February 2021), respectively. Each forage was manually harvested 2 cm above ground level from five randomly selected locations within the paddock. Samples were then mixed and a ~400 g sample of each fresh forage was dried at 60°C for at least 72 h using a standard laboratory drying oven. Thereafter, each dried sample was ground finely, using a 1.5 L blender and subsequently used for the determination of major nutrient and vitamin E concentrations (Table 1). The data consisted of a homogenised forage sample from a single paddock of each forage type, collected once in each season, and were not subjected to statistical analysis.

Variation in lipid and metabolisable energy concentrations between seasons in lucerne and chicory forages were negligible, but for perennial ryegrass, values were reduced by 48% and 22%, respectively (Table 1). Vitamin E concentration of lucerne was elevated by 24% during summer, but in perennial ryegrass and chicory, concentrations were reduced by 72% and 54%, respectively. There was a 70% reduction in crude protein concentration in perennial ryegrass from winter to summer while the variations were small for lucerne and chicory, with 22% and 14% reductions, respectively. Water soluble carbohydrate (WSC) concentration of lucerne was not affected by season but values reduced by 21% and 28% in perennial ryegrass and chicory from winter to summer (Table 1).

Table 1. Nutrient concentration of grass (perennial ryegrass), legume (lucerne) and herb (chicory) forages collected over winter, spring, and summer of 2020 to 2021 in southern Australia (Hamilton, Victoria)[A]

Proximate measure	Perennial ryegrass			Lucerne			Chicory		
	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Lipid (%)	3.3	3.5	1.7	2.9	3.0	2.9	4.7	4.6	4.7
Vitamin E (mg/kg)	24.8	19.0	6.8	39.5	31.6	51.7	69.3	32.9	31.6
Crude Protein (%)	16.6	14.0	4.8	32.3	30.1	25.1	28.0	19.6	24.2
Metabolisable energy (MJ/kg)	10.2	10.4	8.0	10.9	10.6	10.2	12.3	11.2	11.0
WSC (%)	15.3	16.4	12.1	8.7	8.8	9.9	10.3	7.6	7.4

[A]Values are expressed on dry matter basis, determined for each forage sample.

Both lucerne and chicory forages were able to retain lipid and energy concentrations during hot summer conditions at values similar to that of winter and spring, but this was not observed with perennial ryegrass. Lucerne also retained vitamin E concentrations better than the other two forages. The order of resilience in maintaining the dietary nutrients over summer were good, moderate and poor for lucerne, chicory and perennial ryegrass, respectively. Results from this observational study suggest that the performance and productivity of grazing animals will be affected as the season changes, due to the observed variation in major nutrient concentrations in forages. We can conclude that with climate variability, forages such as lucerne and chicory could be used alone or in combination with other forages (e.g. perennial ryegrass) to maintain the productivity of ruminants, as they retain lipids and vitamin concentrations.

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Differences in feeding practices and supplementation on small ruminant farms in four provinces of Fiji

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The livestock sector is critical in Fiji, being responsible for providing affordable animal protein to the population (Fiji Ministry of Economy 2017). Poor nutrition has been recognised as one of the main constraints to increased productivity on Fijian small ruminant (SR) farms (Cowley *et al.* 2019). It has been assumed that inappropriate supplementation practices allied with poorly managed pastures and high levels of gastrointestinal nematodes leads to significant losses of young stock on SR farms in Fiji (Cowley *et al*. 2019). The potential of locally available feed resources to supplement small ruminants in the region is unknown. This research aimed to find out what feed resources and supplements are being used by farmers in the main sheep and goat producing areas of Fiji and investigate possible differences between provinces.

Feeding practices and feed resources used on SR farms, and barriers to supplementation on farms were analysed using a structured farmer survey (n = 248) in two major divisions (Northern and Western) and four major sheep and goat producing provinces (Ba, Ra, Bua and Macuata). The study was conducted with three SR enterprise types (sheep only, goat only and dual farms). A total of 85 quantitative and qualitative questions were developed and applied using the kobo toolbox app to collect farm data. Due to COVID-19 restrictions, the survey was conducted via telephone during 15–24 December 2021.

Unimproved pastures were present on almost all properties surveyed (Table 1), however the proportion of area for unimproved pasture in each property is unknown. Improved pastures were more commonly used in the Bua and Macuata provinces compared to Ba and Ra provinces. On farms that reported using improved pasture in the Northern division, Koronivia grass (*Bracharia humidicola*) was present on 95% farms in Bua and 88.1% in Macuata and for Western division, Guinea grass (*Panicum maximum*) was present on 100% farms in Ba and 78.1% farms in Ra. The adoption of mineral supplementation was more common in Ba and Ra provinces than Bua and Macuata provinces. Cooking salt (i.e. plain NaCl) was most common mineral supplement utilised on 95% of the farms which reported the usage of mineral supplementation in Ba, 91.2% in Ra, 54.5% in Bua and 75% in Macuata. Concentrate feeding was less common in Bua and Macuata provinces compared with the Ba and Ra provinces. This may be because farms in the Northern division are more remote and have less access to by-products. The most common concentrate utilised in SR farms was molasses. Crop residues and food scraps were not commonly used by farmers except in Ra province where 33.3% of farms utilise crop residues such as green waste from vegetables (80%), root crops peelings (60%), leaves and root crops (65%), fruit waste (25%) and harvested plants (10%). A higher percentage of farmers in Ba and Ra provinces reported the usage of foliage, fodder or harvested grasses to supplement SR stock compared to Bua and Macuata provinces. The types of foliages and fodder that were utilised on Ba and Ra province farms included juncao (39.1%), sugarcane tops (39.9%), elephant grass (28.7%) and local vaivai (56.9%).

Table 1. Feed resources and supplementation practices adopted by sheep and goat farmers in four provinces of Fiji

Feed resources	Northern division		Western division	
	Bua (n = 63)	Macuata (n = 63)	Ba (n = 62)	Ra (n = 60)
Unimproved pasture (%)	88.9	88.9	100	98.3
Improved pasture (%)	63.5	93.7	14.5	53.3
Mineral supplements (%)	17.5	6.3	96.8	56.7
Concentrates (%)	4.8	4.8	40.3	23.3
Crop residues & food scraps (%)	4.8	1.6	8.1	33.3
Foliage, fodders or harvested grasses (%)	12.7	3.2	43.5	63.3

The preliminary results of this study show that there are considerable differences in the adoption of feeding practices and resources by SR farmers in Fiji. These differences seem to be aggregated by provinces which may reflect opportunities available to SR farmers or local farming practices. The results suggests that there is a large proportion of famers grazing Koronivia grass in the Northern division while farmers in the Western division have a higher adoptability of concentrate supplementation such as molasses and mill mix. These results may be used as a guide when implementing capacity building and extension courses in the regions surveyed, to target the needs of farmers based on farm characteristics. In addition, researchers can focus on further developing feeding methods and alternatives based on resources that are already commonly adopted by farmers.

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Effects of different heatwave durations on sheep rumen microbial diversity

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Climate change and global warming have increased the frequency of extreme events worldwide. In recent years, Australia has witnessed witnessed increase in the number of extreme heatwave events, which resulted in animal welfare issues and mortality (Nairn and Fawcett 2015). Much research has been done on the impact of heatwaves on animal behaviour, physiology, and other production characteristics. However, very little research has been conducted on the effects of heat stress on the rumen microbiome. Hence this study aimed to evaluate the impact of heatwaves of different durations (1, 3 and 5 days) on the microbial diversity in sheep rumen fluid.

An experiment was conducted at the Dookie campus of The University of Melbourne and was approved by The University of Melbourne Animal Ethics Committee (AEC ID 1914955.1). Twenty Poll Dorset × (Merino × Border Leicester) female lambs were randomly allocated to four groups: thermoneutral (TN), 1 day (HW1), 3 days (HW3), and 5 days (HW5) heatwave treatments, as described elsewhere (Zhang *et al.* 2022). At the end of each heatwave exposure period, lambs were commercially slaughtered, and rumen fluid samples were collected and analysed for changes in microbial diversity using 16S rRNA sequencing.

Overall, among the 10 major abundant phyla identified in the rumen fluid of lambs, *Bacteroidetes* (70.9 ± 2.8%), *Firmicutes* (18.2 ± 3.1%) and *Fibrobacteres* (3.2 ± 1.4%) were the most abundant phyla and *Elusimicrobia* (0.1 ± 0.1%), *Cyanobacteria* (0.1%) and *Tenericutes* (0.1 ± 0.1% were the least abundant phyla. Rumen fluid from lambs exposed to the HW5 treatment had a higher abundance (+6%) of *Bacteroidetes* than the TN group. Conversely, *Firmicutes* were less prevalent (–5%) in the rumen fluid of lambs exposed to the HW5 treatment compared to lambs in the TN and shorter heatwaves. The *Fibrobacteres* population was lower in the rumen fluid from lambs exposed to anyheatwave (HW1: –1.4%, HW3: –3%, HW5: –3%) compared with TN lambs.

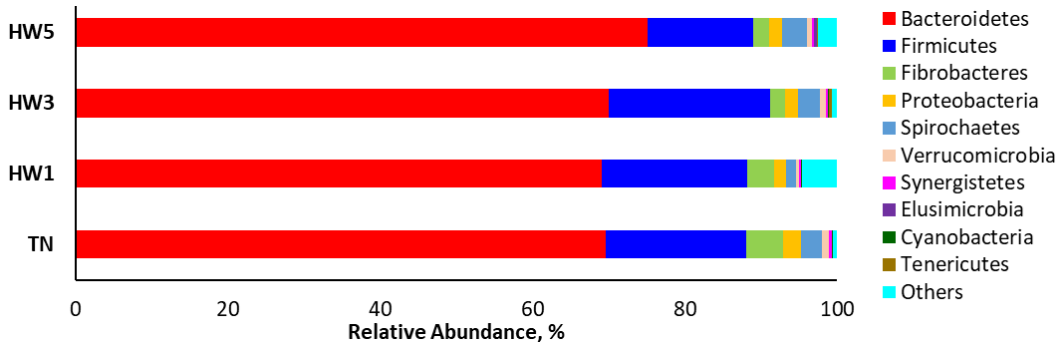

Fig. 1. Phylum level classification of the rumen microbial diversity of lambs exposed to different thermal treatments; TN-Thermoneutral, HW1-1 day, HW3-3 day and HW5-5 day heatwave groups.

These results indicate that the rumen microbiome of second-cross lambs is affected by heatwaves lasting for up to 5 days. The increase in *Bacteroidetes* in the 5HW group compared to the TN group could contribute to a reduction in liveweight of lambs (Turnbaugh *et al.* 2006). Many genera belonging to the *Firmicutes* are positively correlated with the feed conversion efficiency of sheep. Therefore, the decrease in the abundance of *Firmicutes* in the rumen fluid could be associated with a heat stress-induced reduction in liveweight gain of sheep (Myer *et al.* 2015). *Fibrobacteres* play a major role in acetate production and cellulose digestion, and their decreased presence in heatwave groups could negatively affect these processes (Czech *et al.* 2021).

To conclude, our results showed a change in the microbiome diversity of sheep exposed to heatwaves with a more prominent effect on 5 days heatwave. It is hypothesised that prolonged periods may have a more pronounced effect on the rumen microbiome of sheep. Therefore, more extended duration studies involving a larger number of animals are required to demonstrate the impact of chronic heat stress on the rumen microbiome, which may help develop suitable strategies for heat stress mitigation.

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Liveweight gain of intensively fed entire male Rangeland goats

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Traditionally, Rangeland goats have been raised on native vegetation with little or no access to improved forages or supplements. This typically results in slow and inconsistent growth rates of young goats targeted for slaughter (Mills *et al*. 2000). However, with goat meat prices at near historical highs and increased investment in infrastructure on farms (e.g. exclusion fencing), implementation of alternative nutritional management strategies to increase liveweight (LW) gain of male goats for slaughter may be a viable option for Rangeland goat producers. The establishment of on-farm intensive feeding systems may result in a higher turn-off of younger, heavier goats while providing a potential strategy to manage grazing pressure on the feed-base in the rangelands.

Three experiments were conducted to determine the maximum LW gain of intensively fed young entire male Rangeland goats. The experiments were conducted in group feeding pens at The University of Queensland, Gatton, Qld Australia and all procedures were approved by The University of Queensland Animal Ethics Committee. Goats used in each of the experiments were previously used in supplementation experiments (Leo-Penu *et al*. 2022) completed immediately prior to the experiments described here; previous treatments were accounted for in allocation to the treatments described here. In Experiment 1, goats were allocated to either a commercial pellet (n = 27; 20.0 ± 2.7 kg LW; mean ± standard deviation) or lucerne (*Medicago sativa*) hay (n = 27; 19.4 ± 2.3 kg LW) for 64 days, with Mitchell grass (*Astrebla* spp.) hay available as a source of roughage to both groups. In Experiment 2, goats were divided into Light (n = 9; 19.4 ± 3.8 kg LW) and Heavy (n = 7; 30.9 ± 4.3 kg LW) groups and fed the same commercial pellet used in Experiment 1 for 64-days with barley (*Hordeum vulgare*) straw used as the source of roughage. In Experiment 3, goats were separated into Light (n = 40; 19.7 ± 1.9 kg LW) and Heavy (n = 40; 26.0 ± 2.8 kg LW) groups and offered the same commercial pellet and Mitchell grass hay used in Experiment 1 for 42 days. After a 14- or 21-day adaptation period, commercial pellets (Ridley Agri-products; 895 g organic matter [OM], 153 g crude protein [CP]/kg dry matter [DM] with 28 mg monensin/kg) were available *ad libitum* from self-feeders, and lucerne hay (917 g OM, 197 g CP, 400 g ash-free neutral detergent fibre [NDF]/kg DM), barley straw (900 g OM, 38 g CP, 730 g NDF/kg DM) and Mitchell grass hay (892 g OM, 46 g CP, 683 g NDF/kg DM) were available *ad libitum* from hay feeders. All experiments were conducted between December and March in adjacent outdoor earthen floor pens with sufficient shade for all goats and water available *ad libitum*. Goat LW was measured prior to feeding at the commencement of, and every 7- or 14-days during, each experiment. Individual feed intake could not be measured in these experiments as goats were in group pens. Data were statistically analysed using TTEST and GLM procedures in SAS (SAS Inst. Inc., Cary, NC).

In Experiment 1, goats offered pellets had a higher average daily LW gain (ADG) than goats offered lucerne hay (209 ± 11 g vs 132 ± 7 g; $P < 0.001$) across the 64-day feeding period. In Experiment 2, there was no significant difference in ADG between Light (181 ± 23 g) and Heavy (237 ± 33 g) goats across the 64-day feeding period. In Experiment 3, Light goats had a higher ADG than Heavy goats over the 42-day feeding period (150 ± 9 g *v* 85 ± 7 g; $P < 0.001$). The lower ADG of goats fed pellets in Experiment 3 (118 ± 7 g) compared to Experiments 1 (209 ± 11 g) and 2 (205 ± 20 g) may be attributed to the shorter experimental period, as the ADG of goats in this experiment was significantly lower during, the 21-day adaptation period compared to after adaptation (84 ± 9 g *v* 166 ± 9 g; $P < 0.001$). The adaptation period involved a gradual increase in pellet allowances to goats each day, and this was proportionally longer in Experiment 3 (~50%) compared with Experiments 1 and 2 (~25%). There was a large variation in ADG of individual goats fed the pellets within each of the experiments (Experiment 1, range 99–318 g; Experiment 2, range 72–373 g; Experiment 3, range –19 to 350 g). This variation was independent of goat LW and may be attributed to feeding and social behaviour and/or genetic variation of young, entire male Rangeland goats.

These preliminary results demonstrate that young, entire male Rangeland goats can gain an average of 1.4 kg LW/week under intensive feeding conditions. Further research is required to develop recommendations on ration formulation, the introduction of goats to high starch rations, enrichment and health management of goats under intensive feeding conditions, the effects of photoperiod, sex and genetics on intake and LW gain, and the economic and natural resource benefits of establishing an intensive goat feeding system on-farm.

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Characterisation of cattle immune response associated with buffalo fly burden using serum proteomics

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Control of buffalo flies (BF) relies mainly on chemical methods; however, resistance to insecticides is widespread in BF populations. Breeding for resistance to BF represents a possible alternative but direct phenotyping of animals is laborious and often inaccurate. It is known that naturally exposed cattle develop an immune response against BF and closely related horn fly (HF) (*Haematobia irritans exigua*) antigens (Kerlin and Allingham 1992). The response to the latter has been shown to affect HF blood consumption and level of infestation (Breijo *et al*. 2016). In addition, differential antibody responses against *Anopheles gambiae* (*S.*) salivary proteins on naturally exposed individuals have been used as biomarkers to determine host exposure to bites (Rizzo *et al.* 2014). Here we hypothesize that cattle immune response against natural BF infestation varies according to the BF burden, and such variation in immune responses could be used as an indirect indicator of BF burden as well as biomarker(s) for BF resistance.

Thirty-five Brangus steers were phenotyped both by visual assessment and by photographic methods and designated as BF resistant (BF-R) and BF susceptible (BF-S) based on BF burden (five animals in each group). Proteins from serum samples collected at time-0 (pre-exposure to BFs) and post-exposure (at peak fly burden during BF season) were digested into peptides followed by identification and quantification with sequential window acquisition of all theoretical ions-mass spectrometry (SWATH-MS) to measure and quantify the relative abundance of proteins pre-and post-exposure to BFs (Raza *et al*. 2021). Statistical analyses were performed with ReformatMS and MSstats (2.4) in R, with Benjamini and Hochberg corrections to adjust for multiple comparisons and a significance threshold of $P < 10^{-5}$.

SWATH-MS measured the relative abundance of each protein within each individual sample, quantifying 162 proteins by PeakView 2.1 (SCIEX®) with an FDR cut-off of 1%. The intragroup comparison of naïve (before BF exposure) serum samples with the samples collected after BF exposure (BF-R naïve vs BF-R and BF-S naïve vs BF-S) showed that BF exposure upregulated multiple immune-related proteins in BF-resistant cattle, for example, conglutinin, complement component 3 (C3), antithrombin-III and apolipoprotein A-IV (Fig. 1B). In contrast, BF exposure increased the relative abundance of apolipoprotein C-III and antithrombin-III in BF-S, and the abundance of inflammatory mediator, C-X-C motif chemokine was decreased (Fig. 1A), indicating an immune-suppressive effect of BF feeding in BF-S cattle.

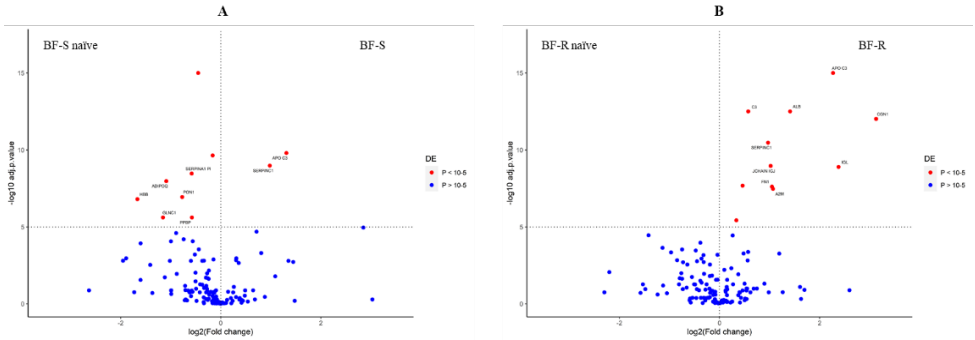

Fig. 1. Volcano plot illustrating differentially abundant proteins between (A) BF-susceptible cattle following exposure to BFs compared to BF-S naïve, and (B) BF-resistant cattle following exposure to BFs compared to BF-R naïve. Red, significantly different in abundance ($P < 10^{-5}$). Blue, not significantly different in abundance ($P > 10^{-5}$).

In addition, intergroup comparison of naïve samples (BF-R naïve vs BF-S naïve) showed that the BF-S group carried two proteins (C3 and vitamin D-binding protein) associated with the immune response at higher abundance than BF-R cattle. However, intergroup comparison of samples following exposure to BFs (BF-R vs BF-S) revealed a higher abundance of immune response and wound healing related proteins in the BF-R group, while the BF-S group showed a higher abundance of proteins associated with wound regulation, inflammation, and inhibition of immune response, such as inhibition of complement system (C4b-binding protein and serpin family G member 1).

These findings suggest that such underlying differences in the abundance of immune response related proteins could be used as indirect indicators of BF burden on cattle and/ or biomarker(s) for identifying BF resistant cattle.

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Low reproduction rates in maiden meat goat does

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The goatmeat sector is expanding and is another Australian red meat industry with a positive outlook. The value of which is underpinned by supply and critical to supply is reproduction efficiency. In an expansion phase there will be great interest in the mating of young (primiparous) females. Little recent work has been undertaken to provide information about reproduction rates in meat goats. This paper reports findings from on-farm investigations into baseline performance.

With the approval of the NSW DPI Orange Animal Care and Ethics Committee (ORA 19/22/002), this study was conducted in one year (2019) at ten different properties across NSW and Qld (Refshauge *et al.* 2020). Mixed age meat goat does were pregnancy scanned to record foetuses per doe (0, 1 or ≥2). All scanned does were managed using commercial practices, decided by the owner/manager, until the does were yarded post kidding, typically at marking. All does and kids were then counted to quantify kid losses and marking rates. Where possible, age of the doe was recorded, enabling comparisons to be made between adult and maiden reproduction rates in herds where on the same farm the maidens (n = 848) remained separate from adult (n = 1306) does from scanning to marking. Data were statistically analysed using the R environment within RStudio (Version 3.6.6) using the linear mixed effects model (*lme4*) (Bates *et al.* 2015). The fixed effect of age class was examined, and herd was a random term.

Comparison of fertility and scanning rates revealed no significant differences between adult and maiden does ($P > 0.05$; Table 1). The survival of kids, calculated by dividing the number of kids at marking by the number of fetuses scanned in mid-pregnancy, tended to be lower in maiden does ($P < 0.1$). The kid marking rate, calculated as the number of kids marked divided by the number of does scanned, was lower in maiden does ($P < 0.05$).

Table 1. Reproduction parameters for adult and maiden meat goats ($\bar{X}$ ± s.e.), number of herds for age class in parentheses[A]

	Adult (4)	Maiden (4)	*P*-value
Does pregnant/doe scanned	0.84 ± 0.08	0.85 ± 0.03	0.62
Kids scanned/doe scanned	1.44 ± 0.17	1.45 ± 0.03	0.76
Kid survival	0.54 ± 0.09	0.35 ± 0.08	0.07
Kids marked/doe scanned	0.75 ± 0.15[a]	0.53 ± 0.08[b]	0.03

[A]Superscripts within the row indicate statistical differences ($P < 0.05$).

Only 4 herds were managing their maidens separately from adult does, affecting the power of analysis. Nevertheless, the pregnancy and scanning rates of maiden does were equivalent to adult does. Kid survival, however, was low in both classes. The kid survival rate in adults (54%) is problematic for the industry but worse in maidens (35%). Given the minor differences in pregnancy and scanning rates, the effect of kid survival is the cause for the difference in marking rates. The seasonal conditions were very severe with intense drought ravaging all farms, where rainfall was in the decile 1 range for the period 1 January 2018 through 31 December 2019. Notwithstanding this, the performance of maidens, in farm systems prepared to manage that age class separately, is rate limiting. In these herds, maidens occupied 39% of all breeders. The practice of exposing young does to bucks requires careful consideration and is likely to involve different management practices to ensure higher kid survival. The adult marking rate (75%) is very low for a meat production animal that produces no alternative commodity, such as milk or fibre. Under conditions of severe drought, these reproduction rates are an existential risk for the industry. Furthermore, the low rates of kid survival are an animal welfare issue. What is urgently required for the goatmeat sector is the validation of reproductive performance across a wider range of farms, undertaken over a longer timeframe to capture greater seasonal variation. Experimentally validated management recommendations need to be developed to increase kid survival under drought conditions.

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Observations on risk of dystocia and lamb survival from high and low birthweight rams

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Dystocia is one of the major causes of perinatal lamb and ewe mortality, and high birthweight is a risk factor for dystocia (Hinch and Brien 2014). The industry trend for selection of rams for high growth rates tends to also select for rams with higher birth weights (Safari *et al* 2005), which may unintentionally reduce sheep welfare through increased lambing difficulties. The aim of this study was to evaluate the incidence of dystocia and impact on lamb production from rams with varying Australian Sheep Breeding Values (ASBV) for birthweight.

The study was conducted with the approval of the Charles Sturt University animal ethics committee (approval 09/011), near Tarcutta, NSW during 2009. Mixed age multiparous Merino ewes were stratified on ewe bloodline, age, condition score and weight and joined in three separate groups to either Poll Dorset (6 rams, 135 ewes) or Composite (based on Poll Dorset × White Suffolk) (two groups of 150 ewes, 7 rams per group) rams. The Composite rams had been divided into High and Low birth weight groups using ASBVs available at the time of purchase. The breeding values shown in Table 1 were calculated on 1 April 2010, downloaded from http://www.sheepgenetics.org.au on 15 April 2010. The accuracies for birthweight ASBVs were between 39 and 64%. After joining, the ewes were managed as one group, and gained 0.1 condition scores in the two months pre-lambing. Two weeks pre-lambing the pregnant ewes (n = 246 ewes) were stratified on genotype, condition score (mean 2.7 ± 0.3 sd) and liveweight within foetal classes, and placed in 3 twin-bearing and 3 single-bearing lambing paddocks containing an estimated 2.1 t DM/ha green pasture. Daily lambing data including lamb birthweight was recorded, and ewes were assisted when required. Results are presented as means and frequencies.

The mean birthweight of lambs in all groups was high (Table 1) compared with the optimal of 4.5 to 5.5 kg (Hinch and Brien 2014). The incidence of lambs weighing more than 7.5 kg was relatively high for ewes joined to high ASBV birthweight rams, and was associated with 21% of single-bearing ewes requiring assistance to deliver lambs. Few twin-bearing ewes gave birth to lambs weighing over 7.5 kg (data not shown), and assistance at birth for twins was consistent among ram groups. Assisted lambs were considered dead, replicating commercial conditions. The percentage of single lambs diagnosed as dying due to dystocia was four times larger for lambs born to Composite rams with high compared with low ASBV birthweights. The higher mortality rate of lambs born to the high birthweight group of rams resulted in 8–10% fewer lambs marked per ewe lambing. The mortality of ewes over the lambing period was 3% despite assistance.

Table 1. Mean lamb weights (±sd), survival and incidence of dystocia associated with Composite or Poll Dorset rams with high or low Australian Sheep Breeding Values (ASBV) for birthweight

	Composite High	Composite Low	Poll Dorset
ASBV birthweight (kg)	0.5 (0.4-0.6)	0.3 (0.2-0.4)	0.2 (0-0.3)
ASBV post-weaning weight (kg)	13.2 (9.3-15.7)	9.9 (8.7-11.1)	13.5 (11.9-15.5)
Mean lamb birthweight singles(kg)	6.7 ± 1.2	6.3 ± 0.8	6.3 ± 0.9
Percentage of single-bearing ewes with lamb birthweight > 7.5 kg (%)	28 (13/47)	4 (2/48)	11 (4/36)
Single ewes assisted (%)	21 (10/48)	10 (5/48)	8 (3/36)
Twin ewes assisted (%)	10 (5/50)	11 (5/46)	7 (3/43)
Dystocia deaths of total singles born (%)	17 (8/48)	4 (2/48)	8 (3/36)
Dystocia deaths of total twins born (%)	5 (5/98)	7 (6/88)	5 (4/86)
Unassisted singles surviving to marking/ewe lambing (%)	71	79	81
Unassisted twins surviving to marking/ewe lambing (%)[1]	151	148	142
Mean weaning weight singles (kg)	33.4 ± 5.8	34.6 ± 3.9	30 ± 5.5
Mean weaning weight twins (kg)	26 ± 5.3	27.9 ± 5.4	25.8 ± 4.6

Our results confirm that using rams with genetics for high birth weights can lead to unacceptably high levels of dystocia in single-bearing ewes, reducing lamb marking rates. Our results may have been due to a single ram producing heavy lambs, but highlight the need to ensure all rams in the team have acceptable birthweights. Improved accuracy values for ASBVs at the time of purchase would improve the selection of suitable rams. The rates of assistance in our study were high but within the range of 5 to 25% reported by Scales *et al* (2000) for Merino ewes joined to various breeds. The study highlights the need to minimise dystocia in extensive conditions where assistance at lambing may not be available.

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Associations between high ambient temperature and poor fertility of ewes

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Heat stress has the potential to substantially reduce ewe and ram fertility at temperatures ≥ 32ºC (see review by van Wettere *et al* 2021). Many Australian flocks are mated during months when hot temperatures are expected, but there is a lack of evidence from field data quantifying the conditions when hot temperatures reduce fertility. This study evaluates the potential for heat stress to have contributed to the reproductive failure observed in an experimental flock.

The observations were part of a larger study (Robertson and Friend 2020) conducted near Tarcutta in southern NSW between 2006 and 2010. In 2006, Merino ewes were randomly allocated to treatments, and remained in these groups unless culled, with younger replacements added over the duration of the study. Ewes were joined to pairs of rams in late February 2006, or early February 2007 to 2010, which were rotated with different pairs about every 5 days. In the Winter Lambing treatment, all ewes were joined to Merino rams for approximately 30 days, while in the Split Lambing treatment, ewes were joined to Poll Dorset or Composite (based on Poll Dorset × White Suffolk) rams for 14 days with an expectation that 80% would be mated. All ewes grazed pastures during joining when available, but were grain fed when insufficient. The ewes were in a mean condition score of 3.0 to 3.5 in each year. Shade was available to rams and ewes pre and during joining, although some of the rams used in 2009 were purchased in January so prior status is unknown. The ewes were pregnancy scanned for fetal number approximately 50 days after the removal of rams to determine fetal number. Weather data was recorded every 10 min on the experimental site (Vantage Pro2, Davis Instruments, Hayward, CA, USA).

The percentage of non-pregnant ewes was at expected low levels in 2006 to 2008, but was elevated in 2009 and 2010, particularly in the Split Lambing treatment with the shorter joining (Table 1). High rates of pregnancy were achieved in 2006 to 2008 despite 20–50% of days pre-joining with a maximum ambient temperature ≥35ºC. Few days ≥35ºC occurred during joining. At least 3 consecutive days of ≥35ºC occurred during the pre-joining period in all years, and at least 5 consecutive days occurred during the first week of joining in 2007 and 2009. 2009 was characterised by 14 consecutive days of ≥35ºC covering the week before and the first week of joining. Mean relative humidity was 20 ± 9.0%.at the time of maximum daily temperatures ≥32ºC.

Table 1. Percentage of ewes not pregnant, number of fetuses per pregnant ewe, and number of days during the 50 days pre-joining or 30 days of joining when daily maximum temperature was ≥ 32, 35 or 40ºC for ewes in two joining treatments 2006–2010. Number of ewes not pregnant of those joined in brackets

Variable	Treatment	2006	2007	2008	2009	2010
Non-pregnant ewes (%)	Split Lambing	4 (2/49)	18 (10/57)	18 (12/65)	95 (54/57)	72 (41/57)
	Winter Lambing	3 (2/60)	4 (3/69)	3 (2/69)	15 (11/75)	12 (9/75)
Fetus/pregnant ewe (n)	Split Lambing	1.62	1.45	1.89	1.33	1.69
	Winter Lambing	1.69	1.33	1.70	1.47	1.68
Days ≥32ºC pre-joining		40	22	21	27	38
Days ≥35ºC pre-joining		25	10	13	17	21
Days ≥40ºC pre-joining		2	1	0	6	5
Days ≥32ºC joining		10	18	2	11	6
Days ≥35ºC joining		2	6	0	6	1
Days ≥40ºC joining		0	0	0	4	0
Average min temperature pre-joining		17.8	16.0	17.1	16.8	16.7
Average min temperature joining		13.7	18.9	14.2	17.4	17.3

These observations indicate that high fertility and fecundity are possible despite a high number of hot days during spermatogenesis and joining. Diurnal variation in ambient temperature, and the provision of shade, may have prevented an adverse impact in most years. Factors other than high temperatures may have caused the low fertility observed in 2009 and 2010. However, investigation of breed resilience to heat stress is warranted. A 14-day joining period prevents re-mating in the event of failure to conceive, and is more risky than longer joinings where challenges to fertility are probable. The study highlights the variability in fertility under field conditions, emphasising the need to manage known risk factors.

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The Easy P Project: evaluating a Phosphorus supplementation strategy that is easy to implement in areas that are difficult to access during the wet season in northern Australia

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The substantial production benefits from feeding Phosphorus (P) supplement to breeding females when grazing P-deficient pastures were recently demonstrated and described by Schatz *et al.* (under review), with a very high return on investment due to increased weaning rates, weaner weights, cow weights and reduced mortality rates. However, adoption of P supplementation is still relatively low in northern Australia, with challenges in being able to deliver supplement to difficult-to-access areas during the wet season considered to be a major barrier to adoption (Dixon *et al.* 2019). The 'Easy P' project aims to determine whether an easy to implement P supplementation strategy is an efficient and effective method of supplementation, especially for properties where it is difficult to supplement during the wet season due to inaccessibility of country. The Easy P strategy involves including P in dry season supplement and putting out enough bulk P supplement before the start of the wet season to last through its duration. This paper compares the performance of maiden heifers that were supplemented using the Easy P strategy to those that received a traditional north Australian supplementation strategy of no P in the dry season supplement and regular P supplement delivered throughout the wet season. The hypothesis was that the two groups of heifers would perform similarly.

This study was conducted at the Victoria River Research Station (VRRS), NT, with approval from the Charles Darwin University animal ethics committee (permit A19021). It was conducted in the same two P-deficient paddocks (average Colwell P soil test results: 2.5 and 3.1 mg P/kg) that were used in the study of Schatz *et al.* (under review). In May 2020, 181 × 18-month-old Brahman heifers were stratified on liveweight and randomly allocated to either an Easy P (EP) or traditional supplementation (TS) treatment, to give two groups of similar number (EP = 90, TS = 91) and average weight (EP = 270.6 ± 3.4 kg, TS = 266.3 ± 4.0 kg). The treatments were managed in exactly the same way except for the mineral loose lick supplement allocated to the groups. The dry season supplements were: EP = 25% Urea, 25% Mono Calcium Phosphate (MCP), 10% Gran Am., 40% salt. TS = 25% Urea, 10% Gran Am., 65% salt. The wet season supplement composition was the same for both treatments (42.5% MCP, 7.5% Gran Am., 50% salt) but the EP treatment was given 2 × 1 tonne bulk bags in December prior to the wet season (the top was cut off the bags so cattle could access the supplement and one bag was placed under a shed while the other was left uncovered) while supplement was delivered regularly (usually weekly) to the TS treatment throughout the wet season (25 kg bags of supplement were put into shed covered troughs at two locations). The P source was a high quality MCP (Total P = 22.7%, TAC Value = 85%). It was not possible to measure wet season supplement intake in the EP treatment as it was not possible to weigh the bulk bags at the end of the wet season and there was considerable leaching of supplement by rain in the un-covered bag. However, a visual estimate was that there was about 600 kg of EP supplement remaining at the end of the wet season.

Liveweight was recorded after an overnight curfew on 6/5/20, 1/9/20 and 20/5/21. Heifers were mated to bulls (that had passed a Bull Breeding Soundness Evaluation) from 30/12/20 to 20/5/21. Pregnancy diagnosis using manual palpation and ultrasound to confirm non-pregnancy was conducted on 20/5/21 and again on 25/8/21 to detect any late pregnancies that were not detectable on 20/5/21. Annual growth was calculated as the difference between weight (adjusted for pregnancy) measured on 20/5/21 and 6/5/20.

There was no significant difference between treatments for annual growth (EP = 109.3 ± 2.3 kg, TS = 113.9 ± 2.3 kg, P = 0.16) or pregnancy rate (EP = 95.5%, TS = 94.5%, P = 0.75). These results indicate that the performance of maiden heifers (as measured by annual growth and pregnancy rate) was similar under both supplementation strategies. The project will continue to compare the performance of breeding females under the two supplementation strategies in subsequent years, but these results suggest that it is likely that the Easy P strategy will be an effective supplementation strategy for areas in northern Australia that are difficult to access during the wet season. It is hoped that these results will help to increase adoption of P supplementation in these areas.

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Developing winter forages for the far north Queensland dairy industry

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The far north Queensland (FNQ) dairy industry has historically relied on the use of maize silage in dairy diets either year-round in partial mixed ration systems, or as a supplement in pasture-based systems during dry times. Maize grows very well during summer in the north Queensland environment and has therefore been readily available to farmers at reasonable cost. However, there are several challenges which can significantly impact the quality of the end product. Harvesting the crop at the correct dry matter percentage, lack of contractors and machinery to harvest large areas that mature at the same time, and more recently the impact that fall army worm has had on yields and cost of production. Inclusion of protein in adequate amounts in FNQ dairy diets is also a challenge due to the cost of freight required to transport typically used protein meals such as canola and soybean. Is there an opportunity to grow winter forages in far north Queensland which are higher in protein than maize silage which can offset the high cost of protein meals in cow diets? These crops can be harvested at a time of year when competition for silage contractors and machinery does not exist therefore increasing the likelihood of harvest occurring at optimum crop dry matter.

In 2021, a demonstration site was established on a dairy farm at Malanda. A ten-hectare irrigated site previously planted to summer maize was planted to four winter forage crops in July. Canola variety (var) Hyola, Wheat var. Buchanan, Wheat var. Bennett and Barley var. Shepherd were planted into 1.5 hectares (ha), 2 ha, 2 ha and 4 ha blocks respectively. Crops were monitored regularly for incidence of pest and disease and nutrient deficiencies. Forage samples were taken at different growth stages and analysed for crude protein (% DM), neutral detergent fibre (% DM), starch (% DM) and metabolisable energy (MJ/kg DM) at Forage Lab Australia using NIRS analysis. Yield data (kg DM/ha) was collected intermittently throughout the duration of the demonstration. Table one shows results from forage samples taken at 54 and 82 days post planting. The yield and quality of the Shepherd barley crop was compromised as a result of the fungal pathogen Bipolaris sorokiniana (*Cochliobolus sativus*), common name Spot Blotch. This affected the crop from day 53 onwards. All crops were harvested and ensiled on day 94 of the demonstration.

Table 1. Yield and concentrations (DM basis) of crude protein, neutral detergent fibre (NDF), starch and metabolisable energy 54 and 82 days after planting for four winter forages grown in far north Queensland

Crop	Yield (kg DM/ha)	Crude Protein (% DM)	NDF (% DM)	Starch (%DM)	Metabolisable energy (MJ/kg DM)
Canola var. Hyola*	2745	30.6	25.9	4.6	11.6
Wheat var. Buchanan*	4109	21.1	48.3	1.9	10.6
Wheat var. Bennett*	2997	27.8	41.8	2.3	11.1
Barley var. Shepherd*	3919	17.4	53.7	1.7	10.0
Canola var. Hyola**	4084	13.9	41.6	3.2	9.7
Wheat var. Buchanan**	7865	12.9	48.7	5.7	10.5
Wheat var. Bennett**	4870	15.3	47.8	2.2	10.6
Barley var. Shepherd**	7738	9.6	53.0	4.4	10.3

*Samples taken on day 54. **Samples taken on day 82.

The yield and quality results from this demonstration show that there is potential to grow winter forages in FNQ that are high in quality, versatile and have comparable yields to winter crops grown in other parts of Queensland. Both Hyola canola and Bennett wheat have demonstrated the ability to produce forage with high crude protein (% DM) in a relatively short time (54 days), and both crops demonstrate good regrowth ability which indicates that harvesting the crop multiple times is possible and could provide two silage cuts and a final hay or graze option. The challenge for farmers harvesting at 54 days will be the need to wilt the crop prior to ensiling at a time when drizzly wet weather can occur. Buchanan wheat has been selected for suitability to FNQ conditions and although lower in crude protein (% DM), it yielded very well (11147 kg DM/ha at harvest-day 94) and had no disease issues. Given the susceptibility of Shepherd barley to spot blotch, and the difficulties and expense this presents to the farmer, this variety is not recommended for production in far north Queensland.

Further work is required to determine agronomic best practices and optimum harvest times for these crops in both irrigated and dryland systems. An economic analysis of the cost per kilogram of crude protein produced from Bennett wheat and Hyola canola is required. This result should be compared to the cost per kilogram of crude protein provided by bought in protein meals. The opportunity to grow a crop which can be harvested in September or October (outside of the peak harvesting time for maize silage) could be attractive to dairy farmers in FNQ.

We gratefully acknowledge Dairy Australia and the Queensland Government for funding this work through the C4Milk project. We also gratefully acknowledge the generosity and contribution of Frank, Dawn, Philip and Mark Cuda, Malanda for the provision of land and labour to plant and manage the crops.

Lamb selectivity among grazing brassicas: a cafeteria trial

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Brassicas are a highly nutritious feed source with potential to fill both summer and winter feed gaps for livestock. However, many producers have observed a delay in liveweight gain when introducing livestock to brassicas (Barry 2013) and this may be associated with palatability. A wide range of grazing brassicas have become commercially available, and there may be differences in palatability among cultivars that could translate into longer or shorter delays in uptake and liveweight gain by livestock. Here, we evaluated selective consumption by lambs of genotypically diverse brassica cultivars in a cafeteria trial, where animals were free to choose among the full complement of forages. Our hypotheses were that (1) some cultivars would be consumed preferentially over others, and (2) preferences would be related to nutritional quality.

In late March 2019, we sowed 14 forage crops including 12 brassicas and 2 control cereals in Greenethorpe, NSW (Table 1; one entry, fodder beet, failed to establish). Plots (2.2 m × 25 m) were arranged in a randomized complete block design with four replicate blocks. Each block was individually fenced and contained a water trough. In June, we introduced 13 Merino lambs (45–55 kg) to each block (0.16 ha) and allowed them to graze for 10 days (i.e. ~812 Dry Sheep Equivalent grazing days/ha). All procedures were approved by a CSIRO Animal Ethics Committee. We estimated the available dry matter (DM) before and after grazing using a pair of quadrat cuts of above-ground material in each plot; plant material was dried at 70°C for 72 h, weighed, and ground for nutritional quality analyses. To quantify selective consumption by lambs, we calculated the difference between pre- and post-graze DM as a percentage of pre-graze DM. We analysed the data in R using the linear mixed effects model function (*lmer*) within the package *lme4* (Bates *et al.* 2015). We tested the fixed effects of cultivar and levels of metabolisable energy (ME), crude protein (CP), neutral detergent fibre (NDF) and nitrate, with block included as a random effect.

Cultivar was a significant predictor of selectivity by lambs ($P < 0.001$; Table 1). Oats, kale and raphanobrassica (kale × radish) were most strongly selected for, whilst turnip foliage was largely avoided (we recorded an increase in available DM in most plots over the grazing period). There was no significant effect of ME, CP, NDF or nitrate content on the proportion of available DM consumed by lambs ($P > 0.2$; Table 1).

Table 1. Change in DM after grazing (as a percentage of available DM) and DM concentrations of ME, CP, NDF and nitrate, by forage cultivar[A]

Cultivar	Δ DM (%)	ME (MJ/kg)	CP (%)	NDF (%)	Nitrate (g/kg)
Oats cv. Eurabbie	-78 ± 8 ^{A}	11.4 ± 0.0	21.6 ± 0.4	31.3 ± 0.8	5.2 ± 1.6
Kale cv. Regal	-75 ± 4 ^{A}	12.3 ± 0.1	24.1 ± 0.7	15.2 ± 1.6	18.5 ± 1.5
Raphanobrassica cv. Pallaton	-67 ± 18 ^{A}	12.4 ± 0.1	25.6 ± 0.9	13.6 ± 0.3	13.6 ± 1.9
Kale cv. Sovereign	-64 ± 9 ^{AB}	12.4 ± 0.1	25.1 ± 1.4	15.3 ± 1.2	21.7 ± 1.9
Rape cv. Winfred	-48 ± 4 ^{ABC}	12.3 ± 0.1	22.7 ± 0.9	16.9 ± 0.9	14.0 ± 1.1
Triticale cv. Endeavour	-46 ± 30 ^{ABC}	11.2 ± 0.1	21.6 ± 0.9	32.2 ± 0.3	4.1 ± 1.3
Rape cv. HT-R24	-41 ± 4 ^{ABC}	12.2 ± 0.1	21.1 ± 0.8	16.9 ± 1.4	19.7 ± 2.0
Canola cv. Hyola 970CL	-38 ± 8 ^{ABC}	12.2 ± 0.1	21.3 ± 1.0	18.2 ± 0.9	17.3 ± 2.5
Rape cv. Goliath	-38 ± 9 ^{ABC}	12.1 ± 0.2	22.6 ± 0.9	18.0 ± 1.3	26.6 ± 7.2
Radish cv. Graza	-35 ± 12 ^{ABC}	12.3 ± 0.1	24.7 ± 0.4	17.1 ± 1.0	8.8 ± 1.8
Bulb Turnip cv. Rival	2 ± 6 ^{BC}	12.2 ± 0.1	23.2 ± 0.3	17.3 ± 0.6	26.3 ± 2.2
Bulb Turnip cv. Green Globe	9 ± 5 ^{C}	12.3 ± 0.1	24.4 ± 1.1	15.8 ± 1.0	15.7 ± 4.2
Leafy Turnip cv. Hunter	17 ± 21 ^{C}	12.4 ± 0.1	23.3 ± 0.4	15.4 ± 1.2	20.3 ± 5.4

[A]Values are arithmetic means and standard errors of the mean (SEM); letters indicate least significant differences (LSD) at $P < 0.05$.

This study demonstrated that lambs prefer some brassica cultivars over others, and these preferences may have a genotypic basis. The preferred brassicas were all kale or kale crosses (*Brassica oleracea* var. *acephala*), while the least preferred were turnip and turnip crosses (*Brassica campestris* var. *rapa*). We found no relationship between selectivity and the nutritional quality parameters we assessed. Selective intake could be influenced by plant secondary metabolites found in brassicas, such as glucosinolates and sulphur-methyl cysteine sulphoxide (Barry 2013). Further work is needed to quantify these compounds across forage brassica cultivars to determine whether they are drivers of selectivity by lambs.

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Steer liveweight gain on Redlands *Leucaena leucocephala* (leucaena)-*Urochloa decumbens* (signal grass) pastures in coastal central Queensland

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Cattle liveweight gains in coastal central Queensland are constrained by poorer soils growing lower quality pastures and highly seasonal pasture growth (McLennan *et al.* 1987). However, there are areas of better soils suitable for sown pastures which can produce higher liveweight gains. Leucaena-sown grass-pastures improve productivity by providing high quality forage for longer time periods at higher stocking rates (Bowen *et al.* 2018). Leucaena productivity in coastal Queensland has been limited by the impact of psyllid insects. A psyllid tolerant variety (Redlands) was released in 2012, but limited animal production studies have been conducted with this variety. The aim of this study was to provide data on the comparative performance of cattle grazing Redlands leucaena-sown grass pastures and native grass pastures in coastal central Queensland.

This study conducted at Fairview, Calliope was approved by the Queensland Department of Agriculture and Fisheries (DAF) Animal Ethics Committee. The Leucaena paddock was sown to Redlands leucaena in single rows (10 m spacing) and the interrow sown to *Urochloa decumbens* (signal grass) in 2018. The Native grass paddock contained principally *Heteropogon contortus* (black spear grass) and *Bothriochloa pertusa* (Indian couch). The paddock also had small areas of *Urochloa mutica* (para grass) and *Hymenachne amplexicaulis* (hymenachne) growing in a lagoon. Forty *Bos indicus* cross steers (2020 weaners) were allocated on random stratified initial weight (mean 278 kg) to the Leucaena and Native pasture paddocks (n = 20/paddock). The steers were weighed regularly from induction to the final weighing. In July 2020, 10 Leucaena paddock steers were drenched with 100 ml of the DAF Leucaena rumen inoculum.

From May 2020 to May 2021, steers grazing the Leucaena and Native pasture paddocks achieved a total liveweight gain of 241 kg and 203 kg, respectively. Steers grazing the Leucaena paddock had a higher average daily liveweight gain (ADG; kg/steer.day) than those grazing the Native pasture paddock from June to November 2020 (Fig. 1). Diet quality (measured by Faecal NIRS) was higher in the Leucaena paddock than the Native grass paddock over this period (crude protein 9.5% vs 4.0% at 31 Jul 2020). Rainfall in late October 2020 (103 mm), produced fresh pasture growth and a large increase in ADG for steers grazing the native pasture. From November 2020 to February 2021 rainfall (126 mm) was well below the mean Mt Larcom rainfall for this period (509 mm, 1913–2021), resulting in a decline in ADG for both treatments between February and April 2021.

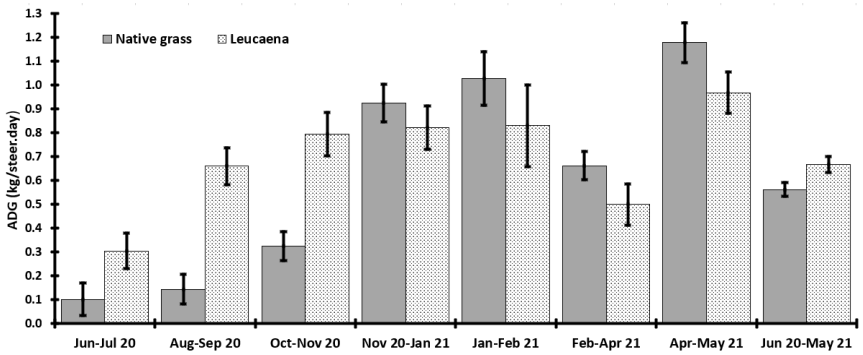

Fig. 1. ADG and 95% confidence intervals for steers grazing Native grass or Leucaena pastures from May 2020 to May 2021.

This trial has demonstrated the potential for leucaena-sown grass pastures to provide higher diet quality and liveweight gains over winter and spring when native pasture quality is usually low in coastal central Queensland. Although total liveweight gain (June 2020–June 2021), of steers grazing the Leucaena paddock was higher than those grazing the Native grass paddock, the difference was not as great as expected. Low leucaena leaf and signal grass biomass from January 2021 until rain in mid-March 2021, contributed to low ADG in the Leucaena paddock from February to April 2021. Compensatory gain and access to *U. mutica* and *H. amplexicaulis* would have contributed to the better ADG of the steers grazing the Native pasture paddock from November 2020 to May 2021.

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Study the impact of heat stress on imported dairy cows in dry zone farm in Sri Lanka

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The changes of body temperature are minimal in cows under favorable and optimal conditions for dairy cattle. The normal body temperature ranges from 38.0°C to 39.5°C in heifers, and from 38.0°C to 39.0°C in adult cows. However, body temperatures that exceed normal values are not ideal, and cows have been shown to decrease their feed intake and heat exchange capacity accordingly (Könyves *et al.* 2017) which in turn causes to lower milk production and reproductive indices (Kadzere *et al.* 2002). The optimal temperatures for dairy cows ranges between 4°C to 24°C and when it reaches 25°C the feed intake decreases and it drastically decreases when the environmental temperature reaches above 40°C and feed intake is 20% to 40% lower than the normal intake (Hahn 1999) Therefore, an observed decrease in feed intake is an important index of heat stress in dairy cows, where the combination of decreased feed intake and increased ambient temperature gradually result in lower milk yield. The cross bred pregnant heifers were imported from Australia to large dairy farm located in dry zone, Sri Lanka. After the quarantine period animals were calved within the period of 3–6 months. Animals were kept in controlled environment since farm environment temperature ranges from 30°C to 33°C and RH ranges from 75–80%. However, the performance of the dairy cows decreases and observed signs of heat stress such as panting, reduced feed intake and lowered milk production. If environmental factors can be actively monitored and management practices altered accordingly to alleviate heat stress in dairy cows, milk yield and quality can be improved by boosting feed intake (Fournel 2017).

The objective of this study was to assess the impact of heat stress on feed intake and milk production of imported dairy cattle, to study the impact of environmental control measures and changing feed on performance of those cows.

Forty Jersey, Friesian cross bred animals imported from Australia were selected for the study. The milk production of these animals were significantly decreased around one to two months after calving. The signs of heat stress including panting, low feed intake and decreased milk production were observed. The animals were kept in loose house barns with temperature controlling facility. The ambient temperature in the farm was ranges between 30°C to 33°C and humidity between 74–80% and THI was 71–74. At the study the temperature control system has been upgraded and removed the fogging system as the THI is higher. Instead in cooperate the showers close to feed alleys so that maintained ambient temperature below 25°C and feed was changed gradually by including molasses and bypass fat.

After two weeks of intervention DMI intake was increased 12.5 kg/day to 13.2 kg/day. The inside temperature of the barn was maintained around 25°C. The THI was decreased from71 to 59. Average per cow milk production increased from 12 L per day to 14.5l per day. When THI > 70 it was shown a decreased average feed intake by 0.6 kg and when THI was <60 the feed intake increased by 0.7kg/day. It was found that increased environment temperature was negatively affected feed intake and milk production whereas controlled temperature and changing feed increased the feed intake and milk production.

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Australian dairy producers' attitudes, practices and intentions to support the management of non-replacement male dairy calves

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Internationally dairy production systems are generating non-replacement male calves that are not suited to commercial outcomes (Weller *et al.* 2017). This economic standpoint has led to the practice of many healthy non-replacement male calves being slaughtered at a young age, commonly less than 10 days of age (Moran 2002; Shearer 2018). In Australia non-replacement male calves are informally called 'bobby calves'. Bobby calves are described to be calves that are less than 30 days old, weight less than 80kg and are of dairy origin. There is estimated to be 400 000 bobby calves processed each year in Australian abattoirs (Dairy Australia Ltd 2020). Many disaggregated production pathways for non-replacement male calves have also led to poor calf welfare and lack of adoption of on-farm rearing (Creutzinger *et al*. 2021; Vicic *et al.* 2021). Previous interviews and questionnaires with Australian and international dairy producers accentuate the intention to continually improve production practices when rearing non-replacement male calves; however, failed avenues to sell non-replacement male calves still lead to unavoidable euthanasia (Maher *et al*. 2021; Vicic *et al*. 2021). Dairy producer wellbeing and its relationship to male calf euthanasia has also been highlighted in previous studies (Wagner *et al.* 2020; Vicic *et al.* 2021) and requires further review.

Qualitative interview outcomes previously described by Vicic *et al.* (2021), focused on attitudes and practices surrounding on-farm non-replacement male calf production and euthanasia practices, supply chain accessibility and perceptions towards the value of dairy beef products. The outcomes from the interviews informed an online questionnaire, that was released to Australian dairy owners and/or managers, online via social media outlets and industry organisations and professionals, from June to October 2021. The questionnaire items also included two scales; Depression, Anxiety and Stress Scales (DASS) (Lovibond and Lovibond 1995) and Personal Wellbeing Index – Adult (PWI-A) (International Wellbeing Group 2013), which were validated to further examine producer wellbeing outcomes discussed in the qualitative study (Vicic *et al*. 2021).

This study received 127 completed online questionnaire responses (Victoria – 64%, New South Wales – 17% Queensland – 6%, South Australia – 6%, Tasmania – 5%, Western Australia – 3%) from Australian dairy producers.

The median age of participants was 42 years of age (youngest 24 years of age and eldest 75 years of age). Most participants both owned and managed their enterprises have worked in the dairy industry for 1–5 years. On average each enterprise had 100–500 milking cows with the predominate breed within each herd being Holstein.

Non-replacement male calf management was divided into three categories: (1) enterprises that did not euthanise non-replacement male calves on farm (84%); (2) enterprises that euthanised some non-replacement male caves on farm (13%); and (3) enterprises that euthanised all non-replacement male calves on farm (3%). From the cohort of participants that did not currently euthanise, 16% of participants said euthanasia use to be a practice due to drought, no demand and/or value of calves and the size of calves were too small for sale (<23 kg). From the other two cohorts of producers who still euthanise some or all non-replacement male calves, 60% said they will continue euthanasia due to the same reasons as above, the capacity of resources on-farm has been reached and the belief that's there is less stress on calf to euthanise on-farm rather than place on a bobby truck at seven days old. The other 40% of producers who still do euthanise some or all non-replacement male calves said they are transitioning to cease euthanasia by using more sexed semen and producing dairy-beef due to the encouraging beef market prices or have acquired larger property and/or are expanded resources to rear calves. The majority (87%) of participants believe dairy beef can target a premium beef market and 85% of respondents believe dairy beef can be marketed as welfare friendly beef products.

In depth analysis of this study is yet to be complete; the next step will be to explore the interactions between attitudes and practices as well as dairy producer wellbeing. This study is projected to be completed by July 2022.

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Administering glucocorticoids to primiparous sows: effects on macromolecule uptake on low birthweight piglets

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Due to competition with maternal resources for growth, gilt progeny is susceptible to restricted development in utero causing slower growth rates and increased mortality. Glucocorticoids are essential regulators of late fetal development, with effects on organ maturation being time specific. As gut maturation in the piglet occurs at the end of gestation, it was hypothesised that treating sows with dexamethasone before farrowing would accelerate enteric maturation in low birthweight piglets (<1.0 kg) and improve macromolecular absorption prior to gut closure.

Primiparous sows were induced to farrow by injections of cloprostenol at 0700 and 1300 hours at 2 d before due date (d114) and assigned either no further treatment (Control) or an intramuscular injection of dexamethasone (20 mg) at 24 h after first cloprostenol injection. When piglets were born, they were given 3 h unrestricted access with sow for colostrum before oral administration of FITC-D (25 mg/mL) to measure rate of intestinal permeability. After ingesting FITC-D solution, piglets were housed in crates under a heat lamp and had blood samples taken at 2 h and 4 h post gavage. Piglet plasma was assayed for FITC-D using fluorescence spectrometry (480 nm, 520 nm) and intestinal permeability was calculated using a standard curve ($r^2 = 0.98$). All data were analysed using general linear model with sow treatment (Dexamethasone; Control), piglet gender, birthweight (low < 1.0 kg; normal >1.3 kg) and litter size (smaller ≤ 11 piglets; larger ≥ 12 piglets) as fixed effects.

The average concentration of FITC-D in piglet plasma increased over time ($P < 0.05$; Fig. 1) but no differences were observed between litters from sows treated with dexamethasone ($P = 0.893$) or between piglets of different birthweight ($P = 0.521$). No two or three-way interactions were observed, but there was a trend towards smaller litters having greater FITC-D absorption at 4 h post gavage ($P = 0.066$; smaller = 14.85 ± 0.5; larger = 17.37 ± 0.92).

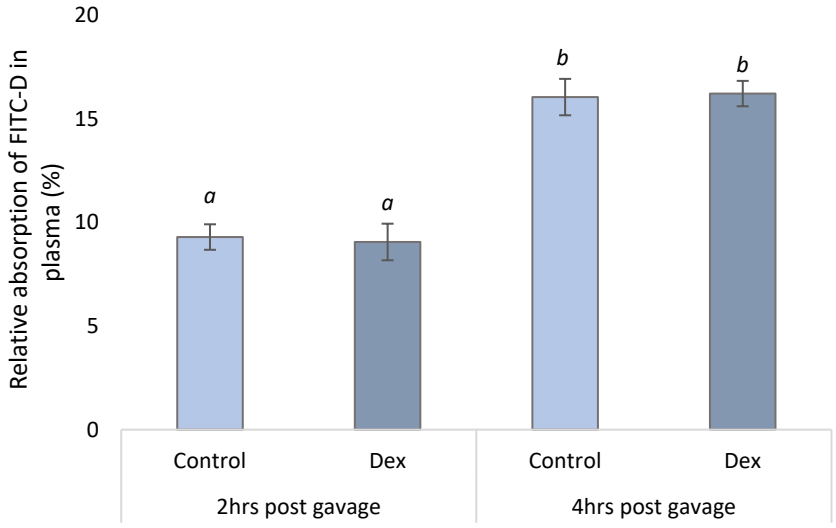

Fig. 1. Effects of dexamethasone (Dex) or Control administered on the day of induced farrowing (day 115 of gestation at 0700 hours) on the relative absorption of FITC-D (25 mg/kg bodyweight) in the plasma of newborn piglets 2 and 4 h after ingestion. Data presented as means ± standard error of the mean and defined as statistically significant when $P \leq 0.05$.

The administration of dexamethasone to sows the day of farrowing did not influence the molecular transfer of FITC-D in low birthweight piglets. From these results, it is not certain whether synthetic glucocorticoids can improve gut performance in low birthweight piglets or whether the timing of treatment needs to be earlier than what was given in this investigation. A trend towards greater FITC-D absorption and smaller litter size was noticed at four hours post gavage. With the intake of colostrum being unmeasured, it cannot be certain whether all low birthweight piglets received a similar amount prior to FITC-D ingestion. Jensen *et al.* (2001) found the absorption of macromolecules increased significantly if piglets were given hourly feeds of colostrum (15 mL/kg/h) and piglets born to a smaller litter may have had greater opportunity to suckle colostrum prior to removal.

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Autumn lambing systems that integrate dual-purpose crops provide benefits across environments

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On-farm feed deficits are becoming more frequent and extreme with a changing climate. Diversifying the on-farm feed base can help combat feed shortages. In southern Australia, lambing time often occurs in spring when feed is most available. Integration of dual-purpose crops (DPC) can provide more reliable winter feed and allow autumn lambing with possible co-benefits of reducing supplementation of lambs over summer and reducing their risk to flystrike and gastro-intestinal worms. Modelling has shown autumn lambing to be possible at Wagga Wagga (McGrath *et al*. 2014), but this has not been tested across a wider range of environments and potential animal health impacts has not been explored. We used the APSIM model (Holzworth *et al*. 2014) to simulate either autumn or spring lambing enterprise, in combination with or without DPC across four diverse environments in New South Wales (Armidale, Gulargambone, Goulburn and Temora). The pasture base was phalaris at Armidale, phalaris and *Microlaena* at Goulburn, lucerne and *Austrostipa* spp. at Gulargambone, and phalaris and lucerne at Temora. Dual-purpose wheat and canola were each sown on 12.5% of the farms most fertile soil types. Ewes also had access to wheat stubble.

At Armidale and Goulburn, autumn lambing systems that integrated DPC had the lowest supplement demand. At Temora, spring lambing systems that integrated DPC had the lowest supplement demand, but at Gulargambone the spring lambing system with pasture only was the lowest. At all locations, autumn lambs were more likely to meet target liveweight (45 kg) than spring lambs. Autumn born lambs grew faster than spring born lambs (~2 weeks), due to access to high quality forage provided by the flush of spring pasture once weaned off the DPC (data not presented). At Armidale and Goulburn, autumn lambing systems that integrated DPC were most profitable, but at Temora and Gulargambone, spring lambing systems that integrated DPC were most profitable.

Table 1. Supplement required to meet animal demand (metabolisable energy, ME), the percent of lambs sold at target liveweight (45 kg), and total farm gross margins for spring- or autumn-lambing system and a pasture only or a pasture + dual-purpose crop feedbase at four locations in NSW. Stocking rates used achieved 40% pasture utilisation rate at all sites

Location	Lamb system	Feedbase	Supplement demand[A] (GJ ME/farm ha/year)	% of supplement fed to lambs	% of lambs sold at target liveweight	Farm gross margins ($/farm ha)
Armidale	Spring	Pasture	2.8	77	18	782
		Pasture + DPC	3.0	73	15	1040
	Autumn	Pasture	3.3	6	72	872
		Pasture + DPC	2.5	2	73	**1158**
Goulburn	Spring	Pasture	4.9	32	15	455
		Pasture + DPC	3.6	57	10	694
	Autumn	Pasture	4.5	2	66	510
		Pasture + DPC	1.8	2	66	**762**
Temora	Spring	Pasture	4.7	0	75	661
		Pasture + DPC	2.2	14	59	**923**
	Autumn	Pasture	3.7	0	80	696
		Pasture + DPC	2.9	0	76	869
Gulargambone	Spring	Pasture	2.5	6	67	944
		Pasture + DPC	4.1	7	53	**975**
	Autumn	Pasture	3.6	2	77	840
		Pasture + DPC	3.8	0	80	902

[A]Supplement demand = supplement fed for maintenance requirements × 13.8 MJ ME/kg DM (ME content of wheat supplement fed).

Integrating DPC improved lamb production and total farm profits universally but this benefit was larger when integrated with autumn lambing systems in higher-rainfall, cooler-winter environments (Armidale and Goulburn). Autumn born lambs grew faster (weaned onto spring pasture) and were sold around early December, reducing supplementation over summer. Lamb production was marginally affected by the 'crop-penalty'; however, higher profits from grain production and lower supplementation favoured DPC. Autumn born lambs were also at lower risk of gastrointestinal worms and flystrike. For example, at Armidale, total livestock mortalities and lamb meat losses from *Haemonchus contortus* infestations were 4.3 and 1.5 times lower, respectively, for autumn lambing systems (data not presented). This modelling analysis suggests that there are opportunities to re-assess lambing time to reduce supplementary feeding over summer and mitigate animal health risks across numerous environments.

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Performance of hybrid Napier cultivars CO-5 (*Pennisetum glaucum* × *P. purpureum schumach*) and Sampoorna (*Pennisetum pedicillatum* × *P. americanum*) harvested at five intervals during Yala season of the year

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Low quality tropical forages are one of the main constraints for ruminant feeding in Sri Lanka leading to low animal productivity. As a solution to this, two hybrid Napier cultivars; CO-5 and Sampoorna were recently introduced and have been described as superior yielding to previous cultivars of CO-3 (*Pennisetum perpureum* × *P. typhodium*) and CO-4 (*Pennisetum glaucum* × *P. purpureum*). The objective of this study were to evaluate the yield and nutrient composition of the CO-5 and Sampoorna Napier cultivars grown under rain fed conditions during the Yala season (May to September).

A 2 × 5 factorial experiment, including two cultivars (CO-5 and Sampoorna) and five harvest intervals (HI; 4, 6, 8, 10 and 12 weeks after planting) was undertaken using a randomized complete block design, with plots 5 m × 2 m in size and each treatment replicated three times. Fertiliser was applied using a blend recommended by Premarathne and Premalal (2006). Planting was undertaken by inserting two stem cuttings (30 - 45 cm long) at 1 m × 1 m spacings. At each harvest interval, plants within a 1 m^2 section in each plot were cut (5 cm above ground level) for determination of fresh and dry weights. A representative sub sample (±500 g) was taken to measure dry matter (DM), crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), *in-vitro* organic matter digestibility (IVOMD) and *in-vitro* metabolizable energy (IVME) content. Data were analysed using MINITAB (16th Version) as a generalized linear model with a 2 factor ANOVA to compare mean differences between cultivars harvested at five intervals.

The DM yield was similar ($P > 0.05$) for the two cultivars but there was a significant difference ($P < 0.05$) between harvesting intervals with DM yield, increasing almost linearly with increasing HI (Table 1). The CP% decreased exponentially with HI with CO-5 greater than Sampoorna ($P = 0.05$; average 9.3% vs 8.7%). Ash% was significantly greater for Sampoorna than CO-5 at 4 weeks, but it then declined more rapidly in Sampoorna, such that the two cultivars were not significantly different from week 8 onwards (C × HI = 0.00). NDF% was similar at each HI except at week 6 when CO-5 was significantly less than Sampoorna (C × HI = 0.00). ADF% was not significantly different ($P > 0.05$) between cultivars, increasing linearly with maturity. Both IVOMD% and IVOME content were not significantly different between cultivars ($P > 0.05$) and was highest between weeks 6 to 8 and 4 to 8, respectively.

Table 1. Yield and nutritional composition of Napier hybrid cultivars CO-5 and Sampoorna at five harvest intervals[A]

Parameter	Cultivar	Harvest interval (weeks)					SEM	Significance		
		4	6	8	10	12	C × HI	C	HI	C × HI
DM yield (t/ha)	CO-5/Sam[B]	1.88^{d}	4.20^{cd}	6.05^{bc}	8.42^{b}	12.54^{a}	0.08	0.16	0.00	0.61
CP (%)	CO-5/Sam[B]	17.9^{a}	11.9^{b}	6.8^{c}	4.6^{d}	3.9^{d}	0.41	0.05	0.00	0.18
Ash (%)	CO-5	13.1^{b}	10.4 ^{c}	8.4^{de}	7.3^{ef}	6.5^{ef}	0.41	0.22	0.00	0.00
	Sampoorna	15.2^{a}	10.1^{cd}	6.8^{ef}	5.5 ^{f}	6.6^{ef}				
	Mean	14.1^{a}	10.2^{b}	7.6^{c}	6.5^{cd}	6.4^{d}				
NDF (%)	CO-5	64.8^{d}	67.7^{cd}	73.5^{ab}	75.7^{ab}	77.6 ^{a}	1.34	0.97	0.00	0.00
	Sampoorna	62.7^{d}	73.9^{ab}	73.3^{ab}	75.9^{ab}	73.7^{ab}				
	Mean	63.7^{c}	70.8^{b}	73.4^{ab}	75.6^{a}	75.7^{a}				
ADF (%)	CO-5/Sam[B]	37.5^{c}	38.7^{c}	42.8^{b}	48.9^{a}	49.9^{a}	0.83	0.11	0.00	0.27
IVOMD (%)	CO-5/Sam[B]	54.0^{b}	58.6^{a}	59.8^{a}	50.4^{c}	46.2^{d}	1.16	0.19	0.00	0.23
IVME (MJ/kg DM)	CO-5/Sam[B]	7.83^{b}	8.63^{a}	8.92^{a}	7.51^{bc}	6.91^{c}	0.17	0.38	0.00	0.08

[A]Values are means. Means within a variable with similar superscripts are not significantly different based on a Duncan's multiple range test ($P = 0.05$). C, Cultivar; HI, Harvesting Interval; SEM, Standard Error of the Mean.
[B]Average of cultivar means (i.e. HI main effect means).

Compared with previous studies on CO-3 and CO-4 cultivars in Sri Lanka (Premarathne and Premalal 2006; Jothirathne *et al*. 2018), CO-5 and Sampoorna were superior in terms of DM yield, IVME and OMD content whilst lower in CP. For both newer cultivars, the highest DM yield was obtained at the 12th week of maturity, but from a nutritional perspective harvesting at the 6th week of maturity during Yala season of the year was optimum for farmers.

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Reproductive efficiency in Angora goats: a cohort study in southern New South Wales

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Poor reproductive efficiency is a well recognised phenomenon of the Angora goat. However, reproductive performance in Australian Angora goats on commercial properties is inadequately described and the causal factors of reproductive inefficiency difficult to ascertain. We present a cohort study conducted in one flock of Australian Angora does in south eastern NSW aiming to identify the major sources of reproductive loss between joining and weaning.

This study was conducted over a 4-year period on a 20.4 ha property in Humula, NSW, 130 km west of Canberra. The flock was established in 2015. Comprehensive reproductive performance records were collected between 2017 and 2021 by the owner. A total of 228 records were available. The flock grazed pasture throughout the year except in 2019. In 2019, a pen research trial was conducted in which pregnant does were fed differentially during different stages of pregnancy to determine the effects of feeding on the skin follicle density of the progeny. These results are presented elsewhere. Does weighing >25 kg prior to joining were selected for breeding. Each year 40-60 does were mated with 2 bucks for a 9-week joining starting in early April. Each year a different oestrus synchronisation protocol was undertaken. Transabdominal ultrasonography for pregnancy diagnosis and fetal number occurred 8 weeks after removal of the bucks. Daily monitoring of the flock began two weeks before the first expected kidding date in early September. For each kid born, the dam was identified and birth type (single, twin) and sex of kid was recorded. Kids were marked at weaning and breeding outcome for each doe recorded. In 2021 only, dead kids (n = 16) were necropsied to identify likely causes of death. Descriptive statistics were conducted using SPSS statistical analysis software.

The overall conception rate (pregnant does/does bred) was 72% or 80% excluding maiden does. Foetal loss from scanning to birth was 17.6–26.9%, although this is likely an overestimation if kids dying during or after birth were not found. Reproductive rates (kids weaned/doe bred) were lowest in maidens (12.1%) and does >15 years (0.0%). Highest rates were observed in does between 3-9 years old (50.9 vs 42.3%, >10 years). Kidding rates (kids born per doe bred) were 67–87%. The majority of births were single female kids (50/153) but females born as twins were more likely to be weaned (78.1%) than single females (72%), single males (52.4%) or twin males (62.1%). Losses between birth and weaning were up to 48% with an overall reproductive efficiency of 50% (50 kids weaned per 100 does bred). Starvation-mismothering-exposure complex was the primary cause of death between birth and weaning. Copper deficiency was suspected to play a role in postnatal mortality based on clinical signs and response to copper supplementation; limited blood sampling (n = 2) substantiated this observation.

Table 1. Reproductive performance of adult does 2017–2021 and mean performance of adults and maidens in one Angora goat flock

Year	No. of does	Oestrus sync	Preg/ doe bred	Foetus/ preg	Doe kidded/ preg	Kid born/ doe bred	Kid born/ preg	Kid wean/ born	Kid wean/ doe bred	Kid wean/ preg
2017	52	Nil[A]	~	~	~	0.830	~	0.860	0.711	~
2019	49	PG[B]	0.694	1.147	0.824	0.673	0.971	0.515	0.350	0.50
2020	49	CIDR + PG[C]	0.837	1.220	0.780	0.796	0.951	0.538	0.429	0.512
2021	45	CIDR + PG[C]	0.889	1.225	0.775	0.867	0.975	0.615	0.533	0.60
Adult	195		0.804	1.20	0.791	0.790	0.965	0.643	0.508	0.539
Maiden	33		0.386	1.111	0.867	0.242	0.867	0.50	0.121	0.622

[A]Nil: no reproductive hormones given.
[B]PG: given 250 mcg cloprostenol IM (Ilium Estromil 1mL, Glendenning NSW), repeated 11 days later.
[C]CIDR + PG: CIDR (Zoetis EAZI-BREED CIDR, West Ryde NSW) inserted for 21 days. Given 250mcg cloprostenol IM at removal.

Conception rates were lower than expected (86-89%; Robertson *et al* 2020). Fetal losses were higher than those reported elsewhere (10.1–20%; Snyman 2010). Postnatal kid mortality was the major source of reproductive inefficiency similar to other reports (Robertson *et al* 2020). Based on a limited number of necropsies, starvation-mismothering-exposure and copper deficiency were the major causes of mortality although the area is not known for copper deficient soils. It is suspected that inadequate pre-joining liveweight is the cause of poor conception rates particularly for maidens. Although this study was conducted in only one flock, there is considerable potential to improve reproductive efficiency. Further research on the wider Angora industry is necessary to develop benchmarks for producers to utilise this potential.

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Protected blend of organic acid, essential oils and fermentation metabolites to control Salmonella

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Historically, *Salmonella* Typhimurium (ST) was the main concern food safety for the egg industry in Australia until 2018, when the first case of food poisoning from table eggs infected with *Salmonella* Enteritidis (SE) was reported. Some nutraceutical products used as feed additives have claimed to reduce *Salmonella* colonisation in birds and thus the shedding of the pathogen, but more testing experiments are required to confirm these findings. Studies with organic acid and essential oils have demonstrated inhibition of the growth of ST in *in vitro* conditions, after culturing them in Mueller-Hinton broth (Zhou *et al*. 2007). In another highly similar *in vitro* assay, the growth of SE was inhibited in Mueller-Hinton agar plates containing different dilutions of a commercial product that combines organic acid and essential oils (Lević *et al*. 2008). There is always need for more *in vivo* studies to evaluate the effect of these compounds against *Salmonella*.

This study was undertaken to examine the effect of the inclusion of a product containing a blend of protected organic acids and essential oils and fermentation extract [P (OA + EO + FM)] on the caecal carriage of a food poisoning related *Salmonella* Typhimurium (ST; Phage Type 135a) after treatment before and after ST exposure.

Day-old chicks were allocated to the four treatments: Group A did not receive any treatment and was not challenged, serving as a negative control. Group B received no treatment and was challenged. Group C received a 1.5 kg/t P (OA + EO + ME) Group D 1.0 kg/t P (OA + EO + ME) and both groups were challenged. At 22 days of age the birds were orally dosed with 1 mL of either sterile broth (Group A) or broth containing 1×10^9 CFU of Salmonella Typhimurium Phage type 135a (Groups B, C and D). At the end of the study, birds were individually weighed, and the results of all the means are compared using one-way ANOVA. At 28 days of age the birds were autopsied, and the caeca removed aseptically for quantitative *Salmonella* testing. Caecal content was extracted from the caeca weighed and suspended at 1:10 (w/v) in buffered peptone water (BPW) + 20% Glycerol. From this suspension, serial tenfold dilutions were prepared in BPW and plated in duplicate on Xylose Lysine Deoxycholate (XLD) agar. Plates were incubated overnight at 36 +/– 1oC. Only colonies displaying a typical Salmonella phenotype on XLD were counted. Results were averaged across the countable range of the dilution series (1–300 suspect Salmonella colonies per plate) and reported as colony forming units (CFU) of Salmonella per gram of caeca. Salmonella colonies were sub-cultured and confirmed by latex agglutination testing and morphology on Salmonella chromogenic agar (Bio-Rad). Group A (control) pools were tested in the same manner as the test groups. A t-test was performed to compare the *Salmonella* counts on each of the treatment groups against the positive control group

The results obtained in the present study demonstrated a positive effect of P (OA+EO+FM) at an inclusion rate of 1.0 and 1.5 kg per MT of feed. The positive effect was observed as a log reduction of the ST content the caeca between 0.61 and 0.66. The broilers from those groups also had a higher average weight at the end of the study compared to those from the PC group, with similar weights to those of the NC group. The ST challenge used in the present study is much higher than would be expected in a field challenge, (a necessity when undertaking assessment of potential control methods to ensure adequate infection in the positive controls) and therefore the achievement of this level of reduction in ST concentration is likely to have a significant impact on reduction of ST levels in a commercial flock under natural challenge conditions.

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Negative impacts of heat stress around farrowing on sow physiology and piglet survivability

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Increased frequency and intensity of heatwaves may compromise sow reproductive efficiency over the summer months. Heat stress (HS) can lead to sow distress, reduced feed intake and farrowing complications, with lasting consequences to both sows and the piglets. Late gestating sows are particularly sensitive to environmental HS as the reduction in feed intake and upregulation of thermoregulatory responses might lower energy status of the sow and affect the farrowing kinetics, possibly increasing the incidence of stillborn piglets (Feyera *et al.* 2018). The objective of this study was to quantify the negative impacts of HS in the lead up to and during farrowing on sow physiology and piglet survivability at birth.

This animal study was approved by The University of Melbourne Animal Ethics Committee. Sixteen pregnant primiparous sows (gilts) were individually housed in farrowing crates and were exposed to either thermoneutral control (CON; constant 20°C, $n = 8$) or cyclic heat stress conditions (HS, 30°C between 0900 and 1700 hours; 28°C between 1700 and 0900 hours, $n = 8$) from d110 of gestation until farrowing completion. Sow respiration rate, skin temperature and rectal temperature were recorded twice daily at 0900 and 1500 hours. Daily blood samples were collected via sow ear vein catheters for blood acid-base analysis. At birth, piglet birth weight, stillborn/born-alive number, meconium staining score and rupture of umbilical cord were recorded. Data were analysed by ANOVA in Genstat.

Heat stress enhanced thermoregulatory responses of sows as evidenced by higher respiration rates (106 vs 31 breaths/min, $P < 0.001$), rectal temperatures (39.4 vs 38.2°C, $P < 0.001$) and skin temperatures (38.1 vs 34.0°C, $P < 0.001$). The increased respiration rate contributed to respiratory alkalosis in HS sows evidenced by higher blood pH values (7.53 vs 7.46, $P < 0.001$) than CON sows. Heat stress decreased sow average daily feed intake by 58% in the lead up to farrowing (1.46 vs 3.50 kg, $P < 0.001$). Heat-stressed sows had lower litter weight (born-alive piglets) than sows from the CON group ($P = 0.018$; Table 1). Sows from the HS group farrowed more stillborn piglets per litter than CON sows ($P = 0.002$). Piglets born to HS sows had higher meconium staining scores ($P = 0.008$). The number of piglets born with a ruptured umbilical cord was increased in the HS group compared to the CON group ($P = 0.002$; Table 1).

Table 1. Effect of sow heat stress (28 to 30°C) between d110 until farrowing completion on farrowing performance and piglet measurements

Variable	Treatments		SEM	*P*-values
	Control	Heat stress		
Total born (n)	13.4	14.0	1.07	0.71
Averaged piglet birth weight (kg)	1.29	1.22	0.06	0.49
Litter weight (incl. stillborns, kg)	16.7	16.5	1.63	0.96
Litter weight (born-alive, kg)	16.5	10.1	1.61	0.018
Born-alive piglets per litter (n)	12.6	8.6	1.51	0.090
Stillborn piglets per litter (n)	0.13	5.30	0.94	0.002
Piglet meconium staining score	0.47	1.14	0.15	0.001
Piglet born with a ruptured umbilical cord (n)	1.17	4.30	0.80	0.002

This study demonstrated that sows were susceptible to even relatively mild HS in the lead up to and during farrowing. Heat-stressed sows had lower daily feed intake and altered physiological status. In conclusion, exposing sows to elevated temperatures around farrowing increased the risk of stillborn piglets and reduced the number of born-alive piglets per litter. These results underscore the need to mitigate the effects of HS in farrowing sheds during the summer months to prevent stillbirths and maintain efficient production.

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The Australian Sheep Sustainability Framework- a world first

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Sustainability frameworks enable industries or organisations to identify and report on important sustainability practices that they are undertaking (Seuring and Muller 2008). The Australian Sheep Sustainability Framework (SSF) was launched by Sheep Producers Australia and Wool Producers Australia in April 2021 (Anon 2021), after extensive consultation with industry and other key stakeholders along the value chain. It is the first sustainability framework for a sheep industry anywhere in the world. The aim of this paper is to describe the development, purpose and details of the Australian Sheep Sustainability Framework.

The SSF was developed by an industry-led Steering Group to report data on sustainability priorities identified as being important to stakeholders. Informed by the AA1000 AccountAbility Principles (2018) and the GRI Standards (2016), an initial Materiality Review identified topics for the development of a first draft, which was progressively modified through the extensive consultation process. Between, February 2020 and February 2021, four consultation phases occurred: one-on-one discussions with key industry stakeholders; three online discussion forums with industry and external stakeholders; an online public consultation; and a final online discussion with state farming organisations. The Materiality Review was updated based on the consultation process, and a final document was then approved in March 2021 by representatives from Sheep Producers Australia and WoolProducers Australia, the initiators of the SSF, prior to its launch in April 2021.

The SSF defined sustainable sheep production as 'Producing sheep meat and wool by current and future generations in an ethical and environmentally, socially, and financially responsible manner'. The SSF covers both sheepmeat and wool production. While the vast majority of wool is processed overseas, the SSF's initial reporting boundary will be restricted to Australian activities, due to concerns over obtaining accurate data from overseas processors / manufacturers. It is hoped to expand this boundary over time.

The SSF identified 21 priorities, with 41 performance indicators and 60 metrics across four themes: Caring for our Sheep (17 metrics); Enhancing the Environment and Climate (14 metrics); Looking after our People, our Customers and the Community (15 metrics); and Ensuring a Financially Resilient Industry (14 metrics).

A formal assessment of the alignment of the SSF with the 17 UN Sustainability Development Goals and their 169 targets revealed a leading contribution to four goals (UN Goals 2,6,8,12) and a supporting contribution to a further six goals (UN Goals 3,7,9,13,14,15). It also includes a set of principles to guide development and implementation.

Thirty-three (55%) of the 60 metrics were able to be reported at the Framework launch, with data not being available for the remaining 27 metrics at that time. The SSF will produce annual reports, with the aim of providing robust data on all 60 metrics, and thereby demonstrate trends for both the industry and its diverse stakeholders over time on the identified sustainability priorities. The SSF will be a living document, subject to review and refinement in consultation with stakeholders, so that it remains relevant and meets the expectations of all stakeholders.

The successful development of a sustainability framework will better enable the sheep industry to demonstrate sustainable practices, identify areas for improvement, and better communicate with customers and consumers, thereby providing further opportunities to enhance trust and transparency around its sustainable practices. The SSF is not a policy instrument – it will report on practices, but it will be up to the industry to decide if any changes to those practices are needed. It may also inform industry investment. The SSF will not influence or impact on individual arrangements farming businesses have to promote their sustainability practices with specific brands.

The extensive consultation process used to develop the SSF ensured that the sustainability priorities identified reflect the requirements of the sheep industry and its stakeholders. The SSF demonstrates an ongoing commitment to transparency, continual improvement, and engagement on sustainability issues, which will help ensure the Australian sheep industry remains a strong and sustainable industry for its participants and its customers.

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Community attitudes towards the quality of life of pasture-based beef cattle in Australia

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Growing expectations towards the welfare of animals in agriculture are driving industry efforts to ensure standards are being continuously improved. To demonstrate and promote improvement, it is important to establish the current state of animal welfare and to understand existing perceptions of welfare across a broad range of stakeholders. Changes in stakeholder perception can then be tracked over time as improvements within industry are made. A survey was conducted to determine views on the importance of a range of measures in providing evidence of a good quality of life (QOL) to inform the development of a welfare benchmarking system for pasture-based beef cattle in Australia. As part of the survey, the respondents' perception of the QOL currently experienced by pasture-based beef cattle was also assessed. The objective for this part of the survey was to determine how the perception of the current QOL of pasture-based beef cattle varied between key demographic groups.

The survey was open for one month in June/July 2020 and distributed widely online. A total of 597 valid responses were received. Beef experience was categorised as: owned or worked on a beef property in Australia in the past 10 years, worked or studied in roles relating to the beef industry, visited a beef property or never visited a beef property. Consumers were categorised as beef eaters, those who did not purchase or eat beef, and those who purchased beef for the household but did not eat it themselves. Self-assessed knowledge of beef production and perceived QOL were indicated on a 5-point Likert scale. Proportions of respondents across industry experience and consumer categories are presented in Fig. 1.

The relationships between key demographics and perceived QOL were assessed by fitting generalised linear models using R software, with terms for perceived QOL and all or one of the key demographics, plus their interactions. The model with all key demographics showed that beef industry experience and knowledge, consumer group, and remoteness of residence; but not age, gender, or state of residence influenced views on current QOL in this set of respondents.

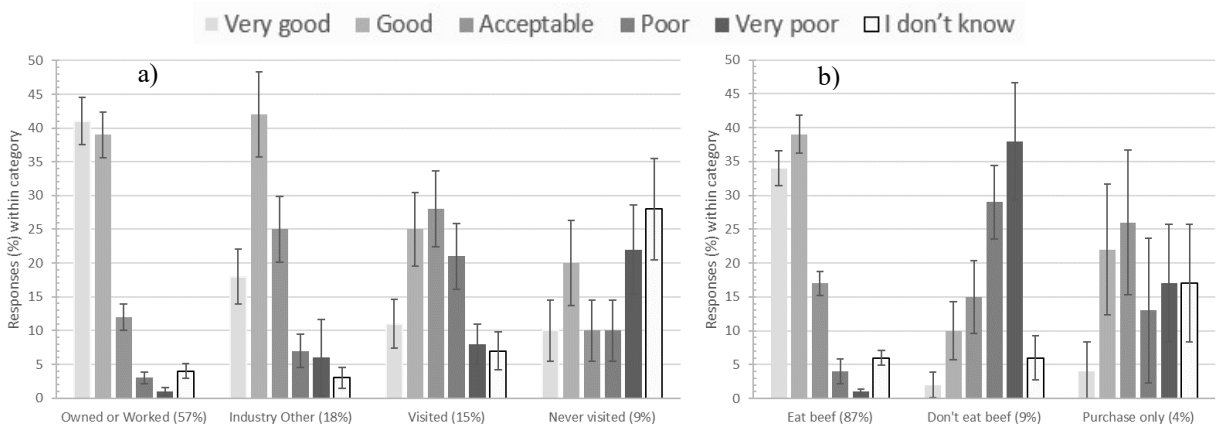

Fig. 1. Surveyed perception (predicted means ± se bars) of the current quality of life of Australian pasture-based beef cattle as influenced by (a) beef industry experience (% of respondents), and (b) consumer group (% of respondents).

Respondents with little to no beef industry experience perceived current QOL to be poorer than those with more experience (Fig. 1a; $P < 0.001$). Similarly, beef non-eaters (Fig. 1b; $P < 0.001$), respondents from metropolitan areas of Australia ($P < 0.001$), and those with limited beef industry knowledge ($P < 0.001$) considered QOL to be poorer than beef consumers, those from remote areas, and those with more knowledge. 85% of people who claimed excellent beef industry knowledge perceived current QOL as very good/good**,** compared to 20% as good only in those with little to no knowledge.

These findings are consistent with those seen in community sentiment research across intensive and extensive livestock industries around the world (Coleman *et al*. 2019, Alonso *et al.* 2020). The community cares about livestock welfare both as consumers and for reasons of public good, and people with more information about livestock production systems are generally more positive about the level of welfare provided. In conclusion, beef industry experience and knowledge, consumer group, and remoteness of residence; but not age, gender, or state of residence influenced perceptions of current QOL. This highlights the importance of developing an objective system which can both drive improvement in the QOL of beef cattle and provide transparent information to all industry stakeholders.

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Thermal heat index and feed management as tools to reduce mortality and improve welfare of livestock on long-haul live export vessels

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Considerable research has been devoted to forecasting heat load and management of nutrition to ameliorate losses for animals in feedlots though such research has not occurred for live export vessels. Managing heat stress in animals is based upon the thermal heat index (THI) (Mader *et al*. 2010). Dry bulb and relative humidity are used to calculate THI on live export vessels. Heat induced stress is one of the most significant challenges facing the live animal export industry. This article proposes feed reduction as an effective strategy in combating heat load on live export vessels. Live-export welfare measurements should be based and assessed on: (i) environmental indices of heat stress, (ii) the animal's response in coping with difficulties, and (iii) signs that coping effects to maintain homeothermy are failing. These factors should be taken into consideration when assessing and implementing new animal husbandry or management techniques.

Metabolic heat is one of the main contributors to the heat load of animals on vessels (Stacey 2001). Thus, it is desirable that this load is accurately described for both sheep and cattle on each live export voyage to give confidence in the decision to tactically reduce feed when required. Other factors such as ventilation and feed composition should also be examined in conjunction with this in the future.

The physical symptoms of heat stress include increased respiration rate, increased sweating, increased heart rate, and increased salivation (Atrian and Shahryar 2012). A reduction of feed intake of between 20–50% of expected daily ration intake will provide a reduction in metabolic heat load symptoms in both sheep and cattle (J. Gaughan, pers. comm., 2021). This will reduce heat stress symptoms of both sheep and cattle on long haul voyages. Sheep and cattle vary in their response to such changes in feed intake, with sheep both being observably quicker to show signs of heat stress than cattle and being quicker to respond to a reduction in feed.

The thresholds indicative of heat stress on journeys have anecdotally been noted as one of the following: a THI of 80 for sheep, a THI of 84 for cattle, a sea surface temperature of 30°C or greater, greater than 20% of animals showing heat stress symptoms, signs of two observable physical symptoms as stated above, and a rate of 15% of feed refusals each day. When one or more of these are observed, some veterinarians on live export vessels will commence reducing feed to stock. Although these feed reduction changes have not been validated in replicated research trials on live export voyages, anecdotal observations across most environmental conditions suggest these methods may be effective in mitigating heat stress. Once a reduction in heat load occurs after successful implementation of this strategy, normal feeding can resume.

Metabolic processes are additive during the development of heat stress in cattle and sheep and, as such, when removed the animal's welfare and behaviour improve as the heat load from feed and other sources is removed. It is therefore proposed that feeding management to reduce metabolic heat at the earliest signs of heat stress in animals be tested to provide an additional tool to manage heat load of animals on live export vessels. Future research should examine the interactions between feeding management, ventilation, seasonal conditions, and THI on welfare outcomes for animals on live export vessels.

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Differences in gut microbiome in free-range laying hens

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Free-range laying production system supplies 52% of the national egg demand (Australian Eggs 2021). Hens in this production system show a broad spectrum of behaviours. Some hens spent 77-80% of their time on the outdoor range while stayer hens spent less than 20% of their time on the outdoor range (Sibanda *et al*. 2020*a*). It is still unclear if the differences in range use, which is associated with egg production, is the cause or consequence of a diverse phenotypic and intestinal microbiota composition. Very little is known about the intestinal microbiota of free-range laying hens to date. A better understanding of the microbiota composition may help to establish better management strategies. Therefore, the aim of this study was to describe the intestinal microbiota of commercial free-range laying hens with divergent body weight and range use.

Three commercial flocks composed of 40 000 hens were used in this study. From each flock, 3125 hens were randomly selected and tagged at 16 weeks of age with Radio Frequency Identification (RFID) leg bands to monitor their movement until 72 weeks. A complete description of the RFID system is provided in Sibanda *et al*. (2020*b*). At 72 weeks of age, hens were classified based on their range use ('rangers' spent more than 75% of their available days on the range; 'stayers' spent less than 10% of their available days on the range) and body weight ('heavy' hens weighing >1.9 kg or 'light' hens weighing <1.70 kg). From this pool, 88 hens were randomly selected and humanely cervical-dislocated to collect caecal content for microbiota analysis. The genomic DNA was extracted from each sample using DNeasy® Powersoil Pro Kit (QIAGEN, Germany). The V1–V3 regions of the 16S rRNA gene were amplified using the primers F-AGAGTTTGATCMTGGCTCAG and R-GWATTACCGCGGCKGCTG. The libraries were then sequenced with the Illumina MiSeq platform (San Diego, CA, USA). The paired-end reads (300 bp) were analysed with the Quantitative Insight Into Microbial Ecology software (QIIME v2021.8) using the DADA2 function (Boyle *et al*. 2019), with 86 samples passing the quality control. The Silvia138 99% database was used with a pre-trained naïve Bayes machine-learning classifier to differentiate operational taxonomic units (OTUs). Four groups were analysed based on the behaviour and body weight: rangers_heavy (n = 22), rangers_light (n = 22), stayers_heavy (n = 20) and stayers_light (n = 22). Variations in microbial diversity were assessed within the sample (alpha diversity) and between samples (beta diversity) together with an analysis of variance (ANOVA) using QIIME2. DESeq v1.34.0 package (Love *et al*. 2014) was used to evaluate differences in microbiota composition between the groups using non-rarefied data.

The amplicon sequence variants (ASVs) identified in the hen caecal digesta had 10,586 features but only 4,330 ASV remained after rarefying corresponding to 1081 OTUs. Three of the most abundant phyla were *Bacteroidetes, Desulfobacterota,* and *Firmicutes*, while *Bacteroides, Blautia,* and *Desulfovibrio* were the most abundant genera. For the alpha diversity, the body weight (P-value < 0.05) and range use_body weight (P-value < 0.01) categories had a significant effect. Significant differences in beta diversity were observed among range use (P-value < 0.05), body weight (P-value < 0.05) and range use_body weight (P-value < 0.05). From the 10 586 ASV identified, there were 1056 ASVs differentially abundant (FDR < 0.05) between the range use_body weight groups. A larger number of significantly enriched ASVs were found when comparing rangers_heavy vs stayers_heavy (n = 607), and a smaller number of enriched ASV corresponded to the rangers_light vs stayers_light comparison (n = 478). The most abundant genera were *Bacteroides*, *Lactobacillus*, *Bacteroides*, and *Helicobacter* in stayers_heavy, rangers_light, rangers_heavy, and stayers_light, respectively.

This study shows that microbial alpha and beta diversity differs mainly among body weight and the range use_body weight groups. A distinct microbial composition was found in range use_body weight groups. Identifying the caecal microbial profile of high producing free-range laying hens and comparing these to the range use_body weight groups would allow in future for potential implementation of probiotics and holistic hen management to improve the health of the birds.

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Air ammonia concentrations under different bedding application rates and air changes in simulated cattle live export conditions

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During long haul livestock sea transport, the accumulation of air ammonia (NH_3) volatilised from the excreted nitrogen (N) in manure is potentially hazardous for human and animal health. Previous studies recommended that the critical threshold of atmospheric NH_3 exposure on vessels are less than 25 ppm for health and safety (Costa *et al*. 2003). The air-NH_3 can be affected by many factors, including bedding and air changes or ventilation. Cattle and buffalo exported on voyages of ten days or more must be provided with sawdust, rice hulls or similar material to be used exclusively for bedding at a rate of at least seven tonnes or 25 m^3 for every 1000 m^2 of cattle pen space (ASEL 2020). Moreover, regulations require air flows at 20 air changes per hour for decks with a ceiling height of 2.3 m or more, and 30 air changes per hour for decks with a ceiling height of 1.8 m (AMSA 2018). The objective of this experiment was to quantify the interaction of bedding application rates and airflow volume on air NH_3 concentration under simulated live export conditions.

This experiment was conducted over two periods between November and February (temperature (°C) average 20.7; min 11.2; max 30.5). Bos indicus cross steers (live weight 240 ± 33 kg, mean ± SD) were used in six experiment runs. For each run, two steers were randomly allocated to each of nine pens for pairing habituation. The pairs then were moved into nine respiration chambers for seven days. Bedding and airflow treatments were randomly allocated among chambers within each run using a 3 × 3 factorial design. The three bedding rate treatments were 0% ASEL (0 kg), 50% ASEL (13.5 kg) and 100% ASEL (27.1 kg) of wood shavings to cover 3.97 m^2 area in each assigned chamber. The three air flow treatments were 20, 35 and 52 air changes per hour. Air NH_3 was measured twice a day, at three different heights, using ToxiRAE Pro handheld monitors. Cattle were fed commercial shipper pellets (91.2% DM, 13.8 % CP, ME 10.72 MJ/kg) at 2% of live weight as dry matter. Air NH_3 concentrations were compared between treatments using mixed models analysis in Stata (Release 16; StataCorp, College Station, TX, USA).

Air NH_3 concentrations were generally low, with only 4% of the 2106 observations over the 7-day period above 10 ppm. The overall *P*-value for interactions between bedding and air change rates was 0.532 and no interactions were assumed. The 95% confidence intervals indicated that any effects of bedding in this context are, at most, modest (Table 1). Mean air NH_3 concentrations from chambers with 35 and 52 air changes/h were similar and lower ($P < 0.001$) than concentrations from chambers with 20 air changes/h (Table 1).

Table 1. Chamber air NH_3 concentration (ppm) by bedding application rates and air changes

Treatment	Air NH_3 concentration (mean ± SD; ppm)	Adjusted difference (ppm)	95% confidence interval	*P*-value[A]
Bedding rate (% ASEL)				
0	5.46 ± 2.44	Reference category		
50	5.20 ± 2.06	–0.3	–1.1 to 0.5	0.524
100	5.46 ± 2.63	–0.0	–0.8 to 0.8	0.994
Air change rate (number per hour)				
20	6.57 ± 1.60	Reference category		
35	4.87 ± 2.98	–1.7	–2.5 to –0.9	<0.001
52	4.68 ± 1.88	–1.9	–2.7 to –1.1	<0.001

[A]Overall *P*-values for bedding rate and air changes were 0.766 and <0.001, respectively.

These results indicate that, under this mild climate conditions, application rate of wood shavings as bedding has no large influence on air NH_3 concentration, and that ventilation management can reduce the risk of high NH_3 levels. These findings may be relevant not only for the live export industry but also for the intensive in-house livestock farms.

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Opportunity to decrease ammonia excretion in cattle urine by varying the crude protein and rumen degradable protein for live export diets

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Feeding cattle with crude protein (CP) in excess of requirements leads to nitrogen (N) retention inefficiency (Mutsvangwa *et al*. 2016). In a high CP diet, feed N that is not metabolised is excreted in urine and faeces as ammonia (NH_3) (Borhan, Gautam, Engel, Anderson, & Rahman, 2013), which in confined housing and live export settings, can lead to air NH_3 concentrations that may exceed safe thresholds for human and animal health and welfare. The current Australian Standard for the Export of Livestock (ASEL) Version 3.0 (2020) requirement for dietary CP is 9–12% DM in diets fed at 2.5% liveweight. Given the level of feeding, this CP content is possibly more than the animals' requirement and may be resulting in higher NH_3 excretion than necessary. This experiment investigated whether there was an opportunity to lower NH_3 excretion in the urine by modifying shipper pellet compositions to lower the CP content while increasing the proportion of rumen degradable protein (RDP).

Eighteen Angus (*Bos taurus)* steers (liveweight 240 ± 20 kg), 12 months of age, were randomly allocated to two cohorts of nine. The steers in each cohort were blocked by liveweight (light, medium and heavy) and randomly assigned to three iso-energetic (8.22–8.32 MJ/kg DM) diets: (1) high CP (11.82% DM) and low RDP (620 g RDP/kg CP, 0.88 g RDP/MJ) commercial shipper diet for live cattle exported from Australia, (2) low CP (9.17% DM) and medium RDP (630 g RDP/kg CP, 0.69 g RDP/MJ) and (3) low CP (9.18% DM) and high RDP (650 g RDP/kg CP, 0.73 g RDP/MJ). All diets were fed at 2.5% LW as a total mixed ration.

After adapting to the diets in individual pens for five days, the steers were housed in metabolic crates for 5 days. All urine was collected (acidified) and sampled five times daily. Urine samples were analysed for daily Total Urinary Nitrogen (TUN) in a Thermo Indiko Plus (ThermoFisher, Vantaa, Finland) using Thermo UREA/BUN reagent (Reagent No. 981820, Urease/UV method, ThermoFisher).

Daily urea-N concentration in the Diet 1 urine samples was higher, around 1 mg/mL.day, than Diet 2 and Diet 3 samples ($P < 0.001$ and 0.017, respectively, Table 1). Daily TUN for Diet 1 and 3 was similar but was significantly lower for Diet 2 ($P < 0.001$). Daily Dry Matter Intake (DMI) was similar for Diet 1 and Diet 2, but was lower for Diet 3 ($P = 0.01$).

Table 1. Daily Urea-N concentration (g/mL) and daily Total Urinary Nitrogen (TUN (g N) by three different diets

Treatment	Daily Urea-N concentration (mean ± SD; mg/mL)	Adjusted difference (mg Urea N/mL urine.day)	*P*-value	Daily TUN (mean ± SD; g N/day)	Adjusted difference (g N/day)	*P*-value
Diet 1	5.05 ± 1.38	Reference category		23.07 ± 5.60	Reference category	
Diet 2	3.40 ± 1.05	–1.66	<0.001	14.37 ± 5.25	–8.7	<0.001
Diet 3	3.92 ± 1.18	–1.18	0.017	19.91 ± 6.36	–3.1	0.141

These results show an opportunity to formulate diets with lower CP but with higher RDP for live export purposes to reduce NH_3 excretion in the urine without sacrificing feed intake. This information may inform refined shipper pellet formulations to increase N efficiency and potentially reduce air NH_3 during livestock shipment.

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The relationship between major fatty acid groups and consumer liking of beef flavour

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Research shows that the fatty acid composition of beef contributes to its nutritional value and oxidative stability. Unsaturated fatty acids are more vulnerable to peroxidation, because of the length and number of carbon-hydrogen bonds. Beef that contains these fatty acids, at various concentrations, will oxidise at different rates and this will affect the profile of volatile organic compounds that are generated upon cooking. The olfactory sensors of a consumer will detect changes to the volatile organic compounds, released with mastication, and use this to inform an individual's liking of beef flavour. This study aimed to determine the relationship between major fatty acid groups and consumer liking of beef flavour. It was hypothesised that beef with higher concentrations of poly- and monounsaturated fatty acids will be less acceptable to Australian consumers, in terms of their liking of flavour.

This study used a total of 40 beef striploins (*longissimus lumborum* muscles), selected at random from a commercial Australian abattoir. These were divided into eight equal portions, vacuum packaged, and aged under one of 72 different temperature-time combinations (Holman *et al.* 2019). Portions were then analysed for their fatty acid composition - as per Ponnamapalam *et al.* (2019) using a capillary gas chromatograph (CP-SIL 88, 0.2 µm i.d., 100 m × 0.25 mm, Varian Medical Systems). The individual fatty acid data (mg/100 g fresh weight) was used to calculate the major fatty acid groups i.e. total saturated fatty acids (∑SFA), monounsaturated fatty acids (∑MUFA), polyunsaturated fatty acids (∑PUFA), omega-3 PUFA (∑n-3), and omega-6 PUFA (∑n-6). Consumer sensory scores, across 40 sensory panels, for beef flavour liking were recorded for these same samples. All of the samples were prepared and allocated to individual consumers using a standardised method (Kilgannon *et al.* 2019). The averaged feedback from untrained Australian consumers (n = 373), who recorded flavour liking on a 100 mm line that was anchored with 'dislike flavour extremely' (0) and 'like flavour extremely' (100). Data were analysed in Genstat (21st Edition) using linear regression models fitted with the fatty acid group as the explanatory term; and both striploin and portion as random terms. A backwards selection regression analysis was also applied to the data. First, each fatty acid group (predictor) was fitted into the same linear regression model. The least significant predictor (with the highest P value) was removed from the model, and the revised model was re-tested. This process was repeated until there were no insignificant predictors to be removed. The significance was set at the 5% level.

Table 1. Linear regression models (± standard error) for the prediction of consumer liking of beef flavour. Data were adjusted for striploin and portion effects

Fatty acid group	Model	*P*-value
∑SFA	0.0003 (±0.0003) + 58.7549 (±2.0315) mg/100 g	0.412
∑MUFA	0.0002 (±0.0003) + 58.6571 (±2.0619) mg/100 g	0.391
∑PUFA	–0.0065 (±0.0060) + 65.1308 (±4.6644) mg/100 g	0.274
∑n-3	–0.0159 (±0.0209) + 62.6530 (±3.4292) mg/100 g	0.445
∑n-6	–0.0069 (±0.0069) + 64.2669 (±4.2429) mg/100 g	0.317

The univariate regression analyses were to predict consumer liking of beef flavour from major fatty acid groups (Table 1). The results show an absence of any relationship between these variables ($P > 0.05$). In response, a backwards selection regression analysis was applied to identify any multivariate relationships between the major fatty acid groups and consumer liking of beef flavour. The product of this analysis was the omission of all the major fatty acid groups from the model, as no effect was significant, in sequence of ∑PUFA, ∑n-3, ∑n-6, ∑SFA and ∑MUFA. This study found there to be no significant univariate or multivariate linear relationship between major fatty acid groups and consumer liking of beef flavour. These results supports the conclusion that beef major fatty acid groups provide little insight into the consumer's satisfaction with its flavour. This conclusion suggests the rejection of the hypothesis, yet further investigation of individual fatty acids, the covariate effects of antioxidants in the beef (e.g. α-tocopherol), background feeding of beef cattle, or the use of a trained sensory panel is first necessary.

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The carcass parameters of intact and castrated male lambs

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Ram (intact male) lambs attract a discounted price at many Australian abattoirs. This is because of their additional processing requirements and the perceived defects in their meat quality, when compared to wether (castrated male) lambs. There are management advantages to rearing wether lambs compared to ram lambs but, in both domestic and export markets, there is an increased awareness of animal welfare that may affect a consumer's willingness to purchase the meat from wether lambs. To inform industry and support market access, we aimed to compare the carcass parameters of ram and wether lambs, that were selected to represent a range of liveweights and that were reared under the same extensive production system (see: McGrath *et al.* 2022 for details).

A total of 50 lambs were slaughtered as a single flock, at a commercial Australian abattoir. Half of these animals were ram lambs and the other half wether lambs, selected so that both groups were balanced by final liveweight. Carcasses were eviscerated, dressed and inspected as per standard industry practice. Individual hot carcass weight (HCW, kg) was recorded at ~ 30 min post-slaughter and immediately prior to their scan with a commercially installed dual energy x-ray absorptiometer (DEXA, Scott Automation and Robotics), to estimate percentage of lean, fat and bone in the carcasses. The change in weight between the live animal and HCW was calculated as the dressing percentage (DRESS, %). Medium voltage electrical stimulation was applied to each carcass before its entry into the holding chiller, whereupon the tissue depth at the girth rib (GR, mm) site was measured. At 24 h post-slaughter, carcasses were fabricated and the loin saddles collected. Eye muscle area (EMA, cm^2), subcutaneous fat depth (Fat C, mm), and fresh colour (L*, a*, b*; Minolta colorimeter, 8 mm aperture, D65-2°) was measured from the exposed LL surface, at the 12th rib. A calibrated pH meter and probe was then used to record LL final pH (PH24, U) and temperature (TEMP24). Data were analysed in Genstat (21st Edition) using linear mixed models fitted with the fixed effect of lamb status (ram vs wether); the random effects of animal; and (for PH24 only) TEMP24 as a covariate. The level of significance was set to 5%.

Table 1. Carcass parameters for ram (intact male) and wether (castrated male) lambs[A]

	HCW	DRESS	Lean	Fat	Bone	GR	EMA	Fat C	L*	a*	b*	PH24
Ram	25.5	53.3	56.8^a	28.8^b	14.5	21.7	14.8	3.1	38.3	17.5	8.1^b	5.51^a
Wether	25.4	53.4	55.4^b	30.5^a	14.2	21.6	13.5	3.8	38.9	17.2	8.9^a	5.37^b
SEM	0.9	0.8	0.6	0.9	0.3	2.2	0.7	0.5	0.5	0.4	0.4	0.04
P value	0.945	0.973	0.024	0.048	0.282	0.957	0.101	0.170	0.308	0.520	0.047	<0.001

[A]Values are least-square means, standard error of the mean (SEM) and the level of significance (*P*-value). Column-wise superscripts indicate different means ($P < 0.05$).

The carcasses of ram lambs contained, proportionally, more lean muscle (1.4 ± 0.6 %) and less fat (–1.7 ± 0.9 %) than the carcasses of wether lambs (Table 1). There was no significant difference in carcass bone percentage or HCW, which is likely the result of the stratified selection of lambs by liveweight. The measures of carcass coverage (tissue and/or fat) were not changed by lamb castration, these included DRESS, GR and Fat C results ($P > 0.05$). The yellowness (b*) of the meat from wether lamb was higher than was found for ram lambs - this being the only observed difference in fresh colour. The PH24 of ram lambs was found to be 1.4 (±0.04) U higher than was found for the wether lambs - with the covariate effect of TEMP24 observed to be significant.

This study demonstrated that ram lamb carcasses have a lower fat percentage, more lean muscle, and provide comparable yields to wether lambs. In addition, for wether lambs, the comparable fat and tissue coverage of their carcasses to ram lambs suggests that their proportional difference in fat tissue is internalised. This was possibly as intramuscular fat, a deposit site that is supported in the literature (Gravador *et al.* 2018). This could prove advantageous when intramuscular fat contributes to the value of a carcass, as proposed by lamb carcass grading systems. It further promotes a need to understand the eating quality and nutritional value of the meat from ram and wether lambs, as these are impacted by fat content. Preliminary insight garnered from the PH24 results does, however, show a difference in the rate of *post-mortem* metabolism (glycolysis) and this will have implications on the consumer organoleptic experience. Irrespective, it is noted that the PH24 for all of the carcasses was aligned to 'hit the window' and therefore produce meat of good everyday eating quality. These findings show a need to contrast the productivity advantages of ram lambs against the carcass quality advantages of wether lambs when deciding to castrate male lambs or leave them entire.

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Liveweight, adrenal gland weight and blood variables of Merino wethers exposed to hot conditions are minimally affected by stocking density

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Climatic conditions, and the resultant heat stress, may have negative welfare impacts on Australian sheep exported to the Middle East during the warm months that occur either side of the Northern Hemisphere summer. The degree of heat stress experienced by animals is strongly influenced by stocking density (Collins *et al*. 2018). Therefore, stocking density is a key environmental factor to consider when housing sheep during live export. However, effects of stocking density under heat load has not been thoroughly investigated in relation to sheep on long haul voyages travelling from Australia to the Middle East, and more evidence is required to define thresholds in stocking density that can safeguard the welfare of sheep being exported during hot periods. The aim of this study was to assess effects of stocking density on the biological functioning of sheep in hot climatic conditions. We hypothesised that reduced space contributes to increased stress, as indicated by liveweight, adrenal gland weight and whole blood variables.

The experiment was undertaken at the Queensland Animal Science Precinct (QASP), Gatton, Qld, Australia, and was approved by The University of Queensland Animal Ethics Committee (ARA 2021/AE000088). Two-hundred and sixteen shorn Merino wethers (39.7 ± 4.25 kg) were housed in 12 pens of 18 head in two climate-controlled rooms, for 21 days. Three animals from each pen (n = 12 per treatment; n = 36 total) were randomly selected as focal animals for physiological sampling and necropsy assessments. Stocking density treatments were selected based on relevance to the industry and corresponded to averages of 0.34, 0.37 and 0.48 m^2 per head. Treatment pens occurred once on each side of the two rooms in a random order; each treatment was replicated four times. The temperature and humidity of both rooms were based on observed climate data collected from a September voyage from Fremantle, Western Australia, to Kuwait. Wet bulb temperatures ranged from 12 to 31°C, with an average of 25.9°C across the 21 days. Blood samples were collected via jugular venipuncture from focal animals on days –2, 0 and 21, where day 0 was the day sheep were moved into treatment pens. Cell counts were obtained on a Sysmex xn-1000 (Sysmex, Macquarie Park, NSW, Australia) haematology analyser, and a manual differentiation was performed. All animals were weighed on day 21, and focal animals were transported to a local abattoir for processing on day 24, where both adrenal glands were excised and weighed. Statistical analyses were performed in Stata (StataCorp, Release 16; College Station, TX, USA) and mixed effects linear regression was used to estimate effects of stocking density on final liveweight, total adrenal gland weight and blood variables.

Results for the effects of stocking density on day 21 liveweights, total adrenal gland weights, and blood variables are shown in Table 1. All *P*-values were high and based on 95% confidence interval (CI) limits, for all variables, any effects are unlikely to be large.

Table 1. Crude means, *p*-values and 95% CIs for day 21 physiological variables in Merino wethers housed in warm conditions under three stocking densities

	Stocking density (average m^2/sheep)			*P*-value	95% CI for effect of a 0.14 m^2/ sheep increase
	0.34	0.37	0.48		
Liveweight (kg)	39.14	39.49	38.41	0.979	–1.46 to 1.50
Adrenal gland weight (g)	1.06	1.08	1.01	0.736	–0.30 to 0.21
Red blood cells ($\times 10^9$ cells/L)	10.72	11.36	11.09	0.805	–1.14 to 0.89
White blood cells ($\times 10^9$ cells/L)	6.99	6.57	6.60	0.188	–1.21 to 0.24
Packed cell volume (L/L)	0.32	0.33	0.32	0.780	–0.03 to 0.02
Haematocrit (L/L)	0.33	0.36	0.34	0.975	–0.03 to 0.03
Haemoglobin (g/L)	99.92	107.00	102.18	0.946	–8.47 to 7.90
Platelets ($\times 10^9$ cells/L)	500.33	430.55	494.82	0.501	–71.71 to 146.60

These results suggest that the biological functioning of sheep was unaffected by stocking density, under the conditions imposed. The results should be considered alongside other welfare assessments to clarify the implications of stocking densities for live export voyages conducted during the warm months that occur either side of the Northern Hemisphere summer.

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Uncastrated Composite lambs grow faster than castrated lambs but the benefit is in the pre-weaning period

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Sheep production in Australia includes routine castration of male lambs at a young age, unless the lambs are to be used for breeding. The reasons for this practice may be both for management ease and marketing considerations (Craigie *et al*. 2012), particularly since ram lambs are currently heavily discounted in the Australian market. Due primarily to welfare concerns, it is becoming more common to leave male lambs uncastrated in many countries, and it is now illegal to castrate lambs in some countries on welfare grounds (Bhatti *et al*. 2019). Leaving ram lambs entire may have positive welfare and production benefits but may also require changes to management such as ensuring lambs reach slaughter age at a young age to avoid meat taint.

The aim of this experiment was to assess the effects on management and production of leaving male Composite lambs uncastrated. This study was conducted at Charles Sturt University (CSU) Farm, Wagga Wagga and was approved by the CSU Animal Care and Ethics Committee. In August 2021 male, Composite breed lambs born in July–August from a mob of ewes that had previously been scanned as single-bearing were systematically allocated to one of two treatment groups at lamb marking, with every other male lamb allocated to the alternate group. Group 1 (n = 133) were left uncastrated and Group 2 (n = 132) were castrated using the Numnuts® system; all other procedures at lamb marking (tail docking, ear tagging and vaccinations) were the same. Lambs were weighed immediately after marking using a lambing box (nearest 0.1 kg) and again at weaning on 28 September (no curfew) and prior to slaughter (after curfew) on 8 December (both to nearest 0.5 kg). Ewes and lambs grazed monocultures of dual-purpose wheat then lucerne prior to weaning, and lambs grazed lucerne-dominant pastures post-weaning without supplementation. Most ewe lambs from the mob were separated from the male lambs at weaning, although there were a small number of ewe lambs still with the males post-weaning. Male lambs (both castrated and uncastrated) were run as a single cohort through until the end of the experiment. Weight and growth rate data for each date or period were analysed using Genstat (Edition 21) using linear mixed models with Random Model 'Lamb' and Fixed model 'treatment'. Means and Standard errors are reported in Table 1. Lambs not recorded or with lost tags were excluded from the analysis on the dates when they were missing.

Ram lambs grew faster (P<0.001) than wether lambs (315 ± 6.6 vs 277 ± 6.6 g/hd.day) in the pre-weaning period, resulting in heavier mean live weights of ram lambs at weaning. There was no difference (P = 0.678) in post-weaning growth rates (190 ± 5.7 vs 187 ± 4.6 g/lamb.day) and the final live weight for rams was greater than for wethers (Table 1). The reduced number of lambs at weaning compared to marking is mainly attributed to loss of tags; there were no lambs reported to have died between marking and weaning. Only two lambs were reported to have died post-weaning; a ram lamb with arthritis in the hindquarters was euthanised, and another lamb (unknown sex) was found dead after becoming flystruck. No management problems were identified by the farm manager during the experiment, however the importance of correct drafting to separate ram and ewe lambs, and the prevalence of mounting behaviour post-weaning by ram lambs was noted. Carcase data from lambs that reached slaughter weight in December was collected to assess treatment effects on carcase traits and meat samples were collected from some lambs for assessment of eating quality and economic value.

Table 1. Mean liveweight (kg ± s.e.) and number of Composite ram and wether lambs at lamb marking, weaning and prior to slaughter

	Rams	Wethers	*P*-value
Marking weight	14.4 ± 0.36 (n = 133)	14.4 ± 0.37 (n = 132)	0.923
Weaning weight	31.1 ± 0.56 (n = 122)	29.1 ± 0.56 (n = 120)	0.014
Pre-slaughter weight	44.6 ± 0.62 (n = 122)	42.5 ± 0.610 (n = 118)	0.018

This study demonstrated that ram lambs can be managed for meat production on a commercial farm and achieve higher finished weights than wether lambs. Surprisingly there was no difference in growth rates of ram and wether lambs post-weaning, in contrast to other studies where ram growth has been superior (Lee 1986). Post-weaning growth rates reported were moderate, and it may be that ram lambs were unable to express superior growth rates due to nutritional or other factors.

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Applying an attention bias test for welfare assessment of sheep – is it repeatable?

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Determining the welfare status of livestock is crucial for maintaining a high standard of animal care, but the emotional states of animals are a vital component of welfare that can be hard to assess. An attention bias test was developed and validated as a measure of anxious states in sheep. Previous studies used drugs to induce calm and anxious states, finding that anxious sheep were more vigilant, paid more attention to a dog threat and had a longer latency to eat during attention bias testing compared to calm animals, validating its use as a measure of welfare status (Lee *et al.* 2016, Monk *et al.* 2018). In this study, we aimed to determine the repeatability of the attention bias test, which has implications if the test is to be applied on-farm for welfare assessment or selection programs. We hypothesised that sheep behaviour would be repeatable but that the mean behavioural responses would change over the trials as they habituated to the test.

This study was conducted at the University of New England and was approved by the University of New England animal ethics committee. Eighty-one 4-year-old Merino and Merino-cross-Border-Leicester ewes were assessed in an attention bias test three times at intervals of 1 year, then 3 weeks. During testing, individual sheep were moved into a 4 × 4 m arena with opaque walls and lucerne hay in the centre. For the first 3 s of the test, a live dog was visible through a window in the wall, then the window was covered and sheep behaviours were recorded for 3 min. Key behaviours included vigilance duration (with the head at or above shoulder height), attention to dog (duration looking at the closed window), latency to eat and eating frequency. Data were statistically analysed using R. Repeatability estimates were obtained using the package rptR (Stoffel *et al.* 2017). The models used to compare mean behaviour across trials are detailed in Table 1.

Table 1. Mean behavioural responses and repeatability estimates in the attention bias test across 3 trials

Behaviour	Least-squares mean ± standard error of mean			Test value[1]	*P* value	*r (95% CI)*
	Trial 1	Trial 2	Trial 3			
Vigilance (s)	157 ± 1.8	154 ± 2.5	153 ± 2.4	$X^2 = 5.27$	0.072	0.58 (0.44, 0.68)
Eating frequency (n)[2]	0.7 ± 0.1 (29)[a]	1.3 ± 0.2 (37)[b]	0.8 ± 0.2 (27)[a]	$X^2 = 15.6$	<0.001	0.36 (0.11, 0.56)
Latency to eat (s)	139 ± 6.7	121 ± 8	141 ± 7.1	LR = 3.49	0.2	0.20 (0.07, 0.34)
Attention to dog (s)	34 ± 0.8[a]	27 ± 1.1[b]	20 ± 1.0[c]	$X^2 = 148$	<0.001	0.08 (0.00, 0.22)

[1]Latency data were modelled with Cox proportional hazards model (LR = likelihood ratio), eating frequency data were modelled using a generalised linear mixed effects model, other data were modelled using linear mixed effects models accounting for repeated measures; [abc]row-wise superscripts indicate different trial means ($P < 0.05$); [2]Raw numbers of ewes that ate are presented in parentheses.

There was no effect of trial number on mean duration of vigilance behaviour or latency to eat ($P > 0.05$; Table 1). However, duration of attention towards the dog wall decreased over the trials while eating frequency peaked in trial 2 ($P < 0.05$, Table 1). The attention bias test compares the relative behaviour of the sheep being tested at any time. Therefore, it will be important to ensure that all sheep being tested have had the same previous experience with the test, in order to make a valid comparison of their relative behaviour.

Duration of vigilance was moderately repeatable as predicted (Table 1). Consistency of behaviour over time can indicate that a behaviour is driven by stable temperament or personality traits. Tests that measure heritable traits can be used for selective breeding. Although heritability of vigilance is yet to be determined, our results suggest the attention bias test may be used to measure trait anxiety, with potential to be applied in breeding programs to select calmer animals. In contrast to our prediction, attention to dog and feeding behaviours had poor repeatability (Table 1). This suggests attention and feeding behaviours were more influenced by temporary emotional states, moods or environmental effects. Although they cannot provide a measure of temperament, the results of previous studies support their use for evaluating state anxiety, which may have applications in research settings and for on-farm welfare assessment protocols.

In conclusion, the results of this study and previous work suggest vigilance behaviour may reflect trait anxiety while attention and feeding behaviours reflect state anxiety in the context of the attention bias test. This means the method has potential to be applied both as a selection tool and a measure of current welfare status, by considering different behaviours during testing. However, further work is needed to determine how these behaviours relate to welfare more broadly before applying the test in a production context.

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Action for Agriculture's school-based programs are helping improve agriculture's social license

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While changing consumer demands and preferences are known to be impacting agriculture's social license, few studies have examined the impact of initiatives seeking to improve agriculture's social license. Since 2012 Action for Agriculture (A4A) has reached over 300 000 students and 400 teachers delivering schools-based programs that seek to build and inspire trust in Australian agriculture. Using a subset of A4A program evaluation data as a case study, our objective was to evaluate if changes in perceptions of agriculture are achievable through school-based programs.

Over two terms in 2018, 32 urban, regional and rural schools (Years 4–12) undertook A4A's cross curriculum aligned project-based learning programs. Science, art, geography and technology was used to explore Australian agriculture. Schools shared their learnings through a digital diary and an artwork on a life-size fibreglass cow (Action for Agriculture, 2021). Each school was paired with a Young Farming Champion; a young agriculturalist role model trained in values-based communication. For program evaluation, during program entry and exit surveys (SERAP no. 2018720) teachers (n = 52) were asked to rank a series of positive statements about agriculture on a Leichardt scale from strongly disagree to strongly agree.

Fig. 1 illustrates the percentage of teachers who strongly agreed with each statement at program exit, compared to entry. Between 36% and 125% more teachers strongly agreed with each positive statement about agriculture at program exit than at entry. For example, the proportion of teachers that strongly agreed, 'Farmers do not hurt their animals. They care about them', more than doubled from 32% to 72%. Student responses showed similar changes (not shown).

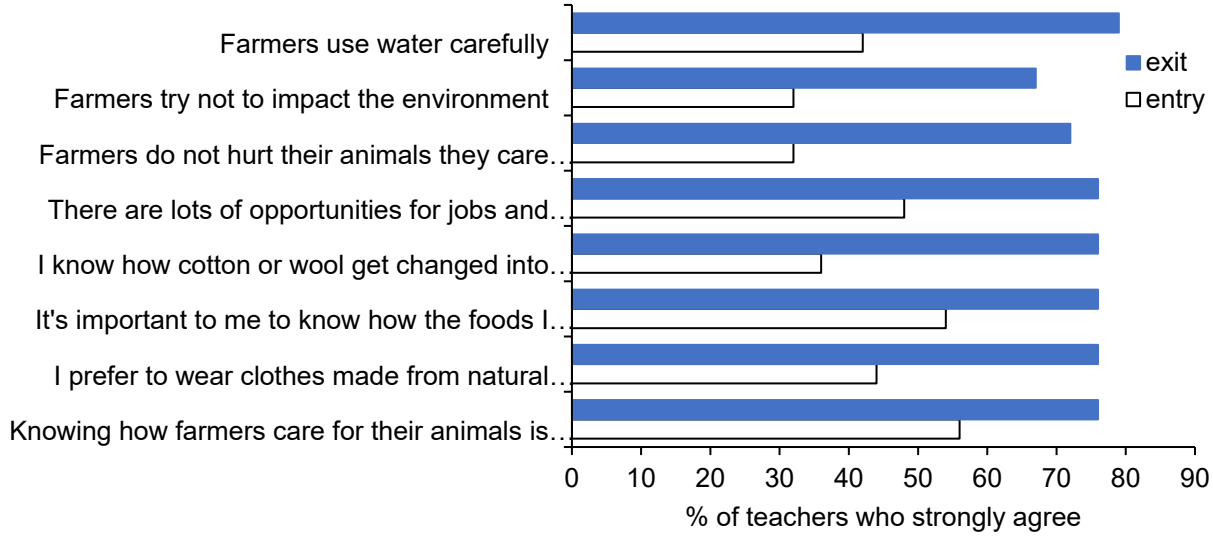

Fig. 1. Percentage of teachers who strongly agreed with positive statements about agriculture at entry and exit to A4A programs.

These results indicate positive changes in perceptions about agriculture have occurred, improving agriculture's social license. Voconiq (2021) found a strong association between positive views about rural industries and knowing someone working in a rural industry. They also recommended facilitating greater connections to people working in rural industries to grow trust. Some of the increase in positive sentiments toward agriculture seen in our study may be attributable to the relationships built between schools and their Young Farming Champions which indicates the need for ongoing Young Farming Champion involvement in A4A program delivery.

In conclusion, this study illustrates curriculum aligned schools-based programs which extend beyond science and build connections between school and agricultural communities are an effective way of building trust, and therefore helping maintain Agriculture's social license in Australia. Improving social licence is not only important for ensuring community support on policy and legislative issues associated with the right to farm, but it is also a strategic way to improve the social sustainability of the industry, improving perceptions of agriculture as a desirable industry in which to pursue a career.

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Startle magnitude is a measure of reactive temperament in sheep

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Excessive reactivity, as one aspect of temperament, may lead to chronic stress and negatively impact on productivity, handleability, stockperson safety and welfare (Rushen *et al*. 1999). Salvin *et al.* (2020) established the startle response as a measure of reactivity in sheep but whether this response is consistent over time and therefore indicative of an underlying temperament trait is not known. Therefore, the objective of this study was to determine whether the startle response in sheep remained consistent across repeated application of the startle stimulus.

Twenty mature dry merino ewes (3-4 years) were used for this study. An additional 6 familiar ewes were placed in pens visually adjacent to the test area to act as social companions during testing. Individual ewes entered the 1.2 × 2.1m test area where a bowl containing food was positioned under the concealed nozzle of an air compressor hose. During a 4- or 7-min test, a 1-s blast of air was delivered to the face of the sheep at a set time after eating had commenced to generate a startle response. Four habituation treatments (*Within Test*, *Hourly*, *Daily*, *Weekly)* were consecutively applied to the same 20 sheep. *Within Test* involved five startles given in one test, *Hourly* involved one startle test given every 2 h for a total of four tests over a day, *Daily* involved one startle test given daily for 4 consecutive days and *Weekly* involved one startle test given weekly for four consecutive weeks. Overall, sheep received 17 replicates of the startle stimulus. Two measures of startle magnitude were calculated from video footage, startle duration (seconds) and retreat distance (zone 1–6).

Statistical analyses were conducted in the R environment (R Core Team 2021; https://www.R-project.org/). Variation in startle magnitude due to habituation treatment was assessed by linear models, and consistency of individual responses was assessed by Pearson's correlations between mean habituation treatment responses. With increasing exposure to the stimulus, there was a significant reduction in retreat distance ($F = 74.51$, df = 3, $P < 0.001$; Fig. 1a) and startle duration ($F = 29.14$, df = 3, $P < 0.001$). The average reaction for individuals within each habituation treatment was positively correlated with the reaction in the other treatments for both retreat distance (Fig. 1b) and startle duration (r = 0.22–0.71).

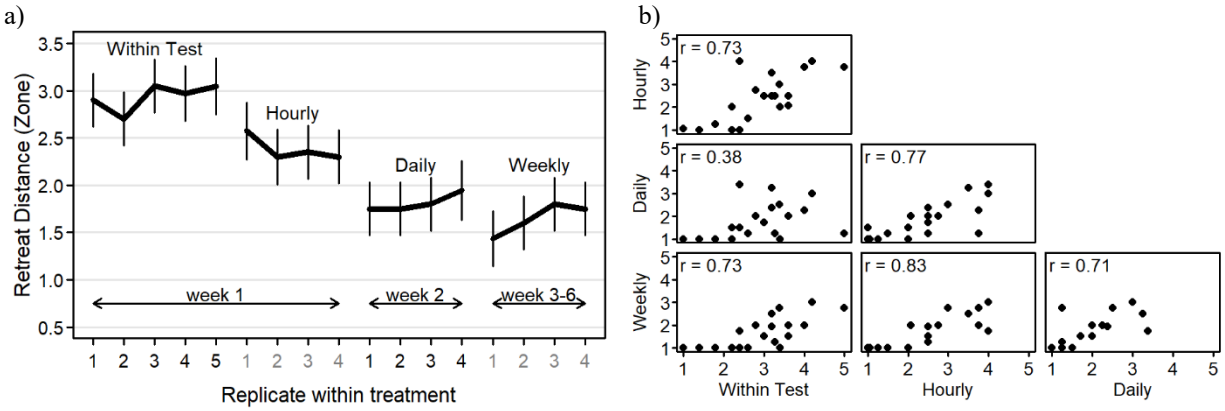

Fig. 1. (a) Estimated mean retreat distance (1–6) across four habituation treatments for a total of 17 replicates over 6 weeks, error bars indicate 95% confidence limits and (b) Pearson's correlation coefficients and plots of mean retreat distance (1–6) across the four habituation treatments for 20 sheep.

This study found evidence of habituation to the startle stimulus consistent with the known effects of non-associative learning or sensory filtering as seen in other species (Valsamis and Schmid, 2011). However, consistent ranking of sheep within the group for startle response was seen across most habituation treatments. This suggests that those with higher startle magnitude could reliably be identified over time as rankings were maintained and, conversely, responses could be used to reasonably predict subsequent reactivity. This repeatability of response also implies startle magnitude is an indicator of an underlying temperament trait. In conclusion, the startle response test provides an accurate assessment of at least one aspect of sheep temperament regardless of any habituation that may occur due to repeated applications of the test. Industry could therefore use startle magnitude to select for sheep with less reactive temperaments, potentially improving handleability, safety and welfare.

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Synchronicity of lying in sheep and its relationship with group size

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Sheep housed intensively, such as on live export boats, can be kept in groups of more than 100 head, but most behavioural studies of sheep have been conducted in groups of less than 10 animals. This research sought to understand how varying group size between 20-100 sheep affects synchronicity of group behaviour. Synchronicity of lying behaviour has become more common as a way of assessing welfare, especially in housed dairy cattle (Napolitano *et al*. 2009), on the basis that it indicates sufficient resources available for all individuals to lie at their own time of choosing.

Group sizes of 20 (n = 8), 50 (n = 4) and 100 (n = 4) sheep were housed in an enclosed shed at an ample stocking density of 1 m^2 per sheep for 5 days and video recorded. The experiment was repeated in 8 runs, testing two treatments at a time. The sheep were fed an *ad libitum* diet of lucerne pellets and oaten chaff. Camera footage (960 h) was then assessed using an instantaneous scan sampling method every 15 min for proportion of animals in a binary lying or standing position. This data was analysed for (1) incidence of 100 % conformity of the group in lying, (2) proportion of the group conforming, and (3) the kappa coefficient of observed to expected proportions of conforming animals, which is not influenced by group size (Asher and Collins 2012), unlike the first and second metrics. The data was evaluated as a mixed effect model (Proc Mixed; SAS statistical package) considering the fixed effect of group size, hour and interaction and run as random effect.

Of 7603 scan records produced by this experiment, the sheep only achieved 100 % conformity for lying in 5.1% of observations, and for standing in 16.2% of observations. Overall, the group of 20 displayed 100% conformity of lying in 8.2% of all observations, compared to 3.8% in the group of 50 and 0.8% in the group of 100. The proportion of animals lying in a pen varied throughout the 24-h period ($P < 0.01$; Fig. 1). On the other hand, the mean proportion of the group lying or standing did not differ across group sizes (mean of 42.0 ± 3.23% of sheep lying and 57.9 ± 3.23% of sheep standing; $P = 0.74$). Moreover, at each hour evaluated, sheep proportion lying and standing was similar among different group sizes (i.e. no interaction between hour and group size; $P = 0.19$). The kappa coefficient did not differ among treatments ($P = 0.12$), thus the observed to expected proportion of conforming animals was 0.494 ± 0.04 across all treatments.

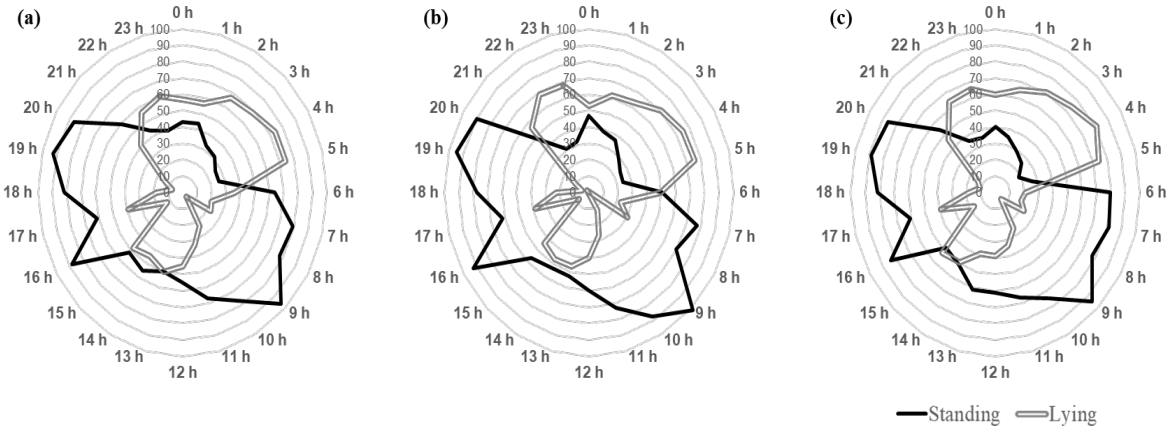

Fig. 1. The average proportion of sheep in a group that were standing (dark solid line) or lying double grey lines) over a 24-h period when housed in a group size of 20 (a), 50 (b) or 100 (c). Grey circles indicate the mean proportion of conforming individuals laying or standing.

The results of the current study indicate that 100% synchronicity of lying behaviour is rare, suggesting 100% synchronicity of lying may not be very useful as a measure of welfare in sheep housed with ample space for short periods. There is no effect of group size on synchronicity of lying behaviour, as the difference in the kappa coefficient is negligible. The results from this study will inform future land-based group housed sheep experiments that will be representing large pen groups of sheep on live export voyages.

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Reduced maternal contact increases piglet behavioural stress during husbandry procedures at 3 days of age

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Routine husbandry procedures are necessary to maintain health and welfare status of livestock species. However, these can be stressful events for animals. At 3 days of age, piglets undergo tail docking, oral drenching with coccidiostat and an intramuscular iron injection, which is one of the first human physical interactions that piglets experience. Early life interactions, such as those with the mother and stock people, have been shown to mitigate stress responses (Lyons *et al*. 2009). It was hypothesised that litters that received maternal contact and positive human contact would display decreased behaviours that are indicative of stress during piglet processing at three days of age.

Fifty-eight sows were allocated to a five-replicate, 2 × 2 factorial randomised blocks design for treatments maternal contact (MC+)/restricted maternal contact (MC–); and positive human contact (HC+)/control, no additional human contact (HC-). Each experimental unit (plot) contained two or three adjacent sows and their litters. Sows were stratified on parity (parity 3.5 ± 0.3) among plots within blocks. Modified farrowing crates were used to restrict maternal contact (MC–). Piglets were fostered within crate type prior to HC+ commencing. Litters in the HC+ treatment received 5 min of daily positive human interaction (patting) if piglets approached the observer. At 3 days of age, piglets were removed from the home crate and were tail docked, orally drenched with coccidiostat and received an intramuscular iron injection, known as processing. The number of sow and piglet vocalisations, struggle attempts and posture changes and sow-piglet interactions during processing were recorded by an observer. Data were analysed using a randomised block ANOVA with treatment combinations divided into the orthogonal contrasts of (i) main effect of HC, (ii) effect of MC within HC– and (iii) effect of MC within HC+, using GenStat 19 (VSN International, Hemel Hempstead, UK).

There were significant decreases ($P < 0.05$) in piglet high pitched vocalisations (squeals), piglet low pitched vocalisations (grunts), piglet struggles and sow posture changes with increased maternal contact when positive human contact was also applied (Table 1).

Table 1. Effect of maternal contact of human contact (HC) and maternal contact (MC) on piglet vocalisations and struggle movements, and sow behaviours during piglet processing at 3 days post-farrow

	HC–		HC+		SED	*P*-value		
	MC-	MC+	MC-	MC+		HC	MC in HC-	MC in HC+
Grunts per litter	42	37	52	36	7.4	0.39	0.49	0.049
Squeals per litter	28	24	38	24	4.4	0.17	0.34	0.010
Struggles per litter	8	8	11	6	1.8	0.74	0.73	0.010
Soft grunts per sow	32	31	21	20	9.3	0.12	0.93	0.92
Aggressive grunts per sow	1.4	0.5	2.2	1.4	1.97	0.55	0.64	0.69
Loud grunts per sow	26	15	24	12	12.3	0.75	0.37	0.34
Nosing of piglets per sow	0.5	2.0	1.5	2.3	0.78	0.27	0.084	0.37
Posture changes per sow	0.9	0.9	1.0	0.3	0.28	0.18	0.19	0. 023

This study demonstrated that reducing maternal contact increases stressful behaviour in piglets in the presence of positive human contact, indicating that maternal contact may affect stress resilience in young piglets. The reason the effect was only observed with positive human contact could be that positive human contact is initially stressful to piglets, and only under this extra stressor was the maternal effect detectable. This differs from Hayes (2021) who reported a reduction in struggle attempts and vocalisations with positive human contact piglets at processing. The increase in posture changes in sows with reduced maternal contact, in the presence of positive human contact, could be a consequential response in the sow to an increase in stressful behaviours of her progeny. In conclusion, these findings highlight the importance of early life experiences in pigs, and future work will examine if these treatments impacts remain through later life stages.

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Australian's do not know much about the pork industry, and don't want to know much either

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The social license debate has shifted in recent years from a focus on 'right to farm' to a broader sustainability narrative in Australia. As pork is embracing a sustainability agenda with bold targets (Australian Pork Limited 2021), we sought to identify the state of community attitudes and knowledge that related to the industry in order to identify barriers and opportunities to promote pork's social license and pork consumption. It was hypothesised that pork has a good standing in the community but would be less understood than other red meats like beef and lamb.

This study was undertaken in May 2020. A qualitative study of 54 participants from metro Sydney and regional NSW, using a mixed methodology of expert interviews and guided focus groups, was undertaken to identify initial key themes. A 15-min online quantitative survey among a nationally representative sample of 2000, based on the 2016 census data, was then undertaken. A further boosted sample (n = 200) for vegetarians and vegan (meat rejectors) was included to identify any trends unique to meat rejectors. The total sample size after data cleaning was 2132. The quantitative data was analysed using Q Research software and SPSS.

Sixty-nine percent of people surveyed had a neutral or 'don't know' opinion of the industry, with only 1 in 5 feeling they were knowledgeable about industry practices. In comparison, only 37% were interested in learning more about the industry. Thirty-one percent of respondents considered the industry trustworthy, with the majority being neutral or unsure (51%). When considering why people eat or reject meat, rejection was linked to sustainability factors (e.g animal treatment, environmental) while pork rejection was mainly due to religious reasons (Fig. 1). Seventeen percent of respondents indicated they were flexitarian (eating meat sparingly) and most of these were born overseas and younger (18–34 years).

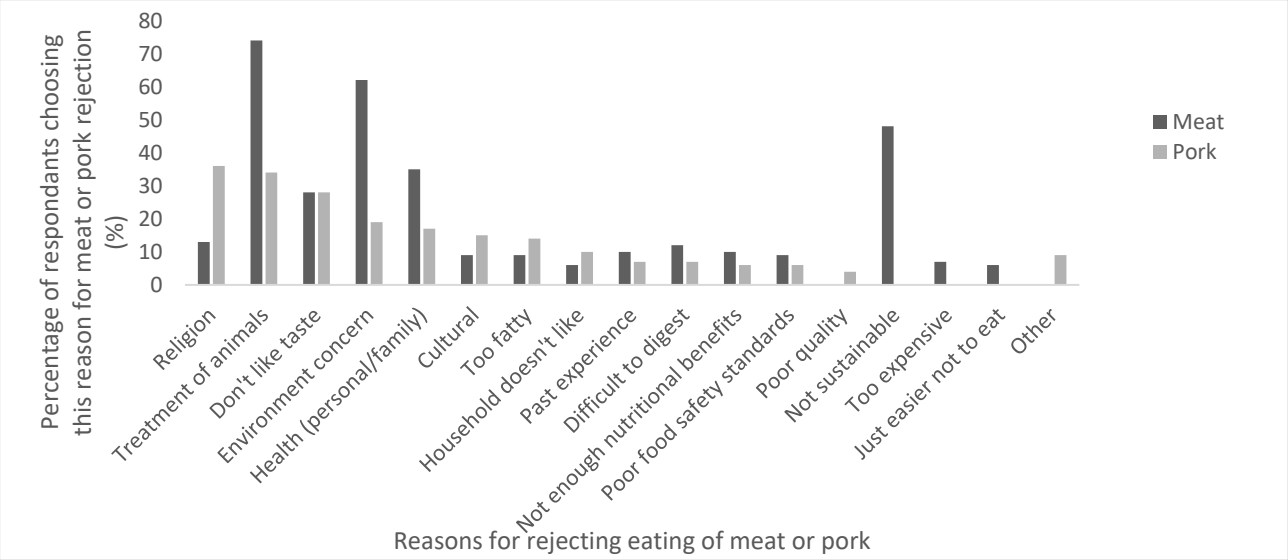

Fig. 1. Reasons given by respondents for not eating meat (n = 201) or pork specifically (n = 163). Note participants were able to select multiple reasons.

This identified a large degree of uncertainty and apathy in regard to the pork industry. Many industries are struggling with issues of social license and decreases in willingness to consume meat products. However, this study showed that the reasons why pork is rejected are cultural or other factors over which the industry has no direct control over. This presents the industry with both a risk and an opportunity for growth through the demonstration of strong action on sustainability. The degree to which respondents were willing to trust the pork industry was lower than rural industries in general which 87–89% of people at least moderately trusted (Voconiq 2021), although this work uses a different scale that didn't allow for neutral/don't know. Another reason for the lower trust may be due to the respondents in this study feeling they knew nothing about the pork industry. Further repetitions of the study are planned to allow analysis of trends over time. This study should be considered a point in time snapshot until the stability of these attitudes through time are confirmed.

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Optimising heifer development and management to increase whole herd profitability

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To maximise lifetime reproductive performance heifers should reach puberty by 14 months of age, conceive early in the breeding season, calve unassisted, wean a calf and get back in calf early. Heifers that do not conceive early generally re-breed late (Day 2015) or not at all and are culled from the system incurring an economic loss. This paper aims to address alternative management strategies to improve re-breeding success of these late calving heifers.

A cohort of 1208, 2018 spring born Angus heifers were weaned in March 2019 and run as a single mob on a large pasture-based system on King Island, Tasmania. Heifers were joined to Angus sires for ~9 week breeding season, pregnancy scan and fetal ageing occurred in February 2020. Heifers were drafted into three mobs/management groups corresponding to their reproductive cycle; 1st, 2nd and 3rd. Heifers remained in management groups post calving for a 6-week re-breeding period, subsequent pregnancy scan and foetal aging occurred in February 2021. The 3rd cycle group were allocated greater feed on offer during calving and early lactation.

Body composition measures; weight, height, rib fat and body condition score were collected at multiple time periods from weaning to the second pregnancy scan, pasture quality and quantity samples were also obtained. Data was analysed using ASReml-R, a number of different models were run, continuous dependent variables were analysed using a general linear model and binary traits analysed using a binary logistic regression.

Heifer conception rates were 89%, with 1st, 2nd and 3rd cycle conceptions rates of 47, 18 and 24% respectively. Re-breeding conception rates were high at 89%, 1st, 2nd and 3rd cycles re-breeding at 89, 90 and 88% respectively, heifers that conceived early in the re-breeding season (first 21 days) was not significantly different (~60%) between management groups (Fig. 1).

There was no difference between management groups and overall rebreeding conception or rebreeding cycle. Heifers that conceived in the first cycle were significantly heavier than the other groups at weaning and through calving. However, post calving 3rd cycle heifers that were allocated more feed were heavier, fatter and in better body condition than the first and second cycle, so third cycle heifers maintained condition and fatness throughout calving and re-breeding while the earlier cycles lost condition and fatness.

Body condition and nutrition have a significant effect on postpartum interval (Funston 2014) but this study concluded that maintaining body condition and fatness resulted in the reproductive success of the 3rd cycle heifers. This result presents producers with the option to separately manage 3rd cycle heifers post calving offering additional feed to increase early re-breeding conception.

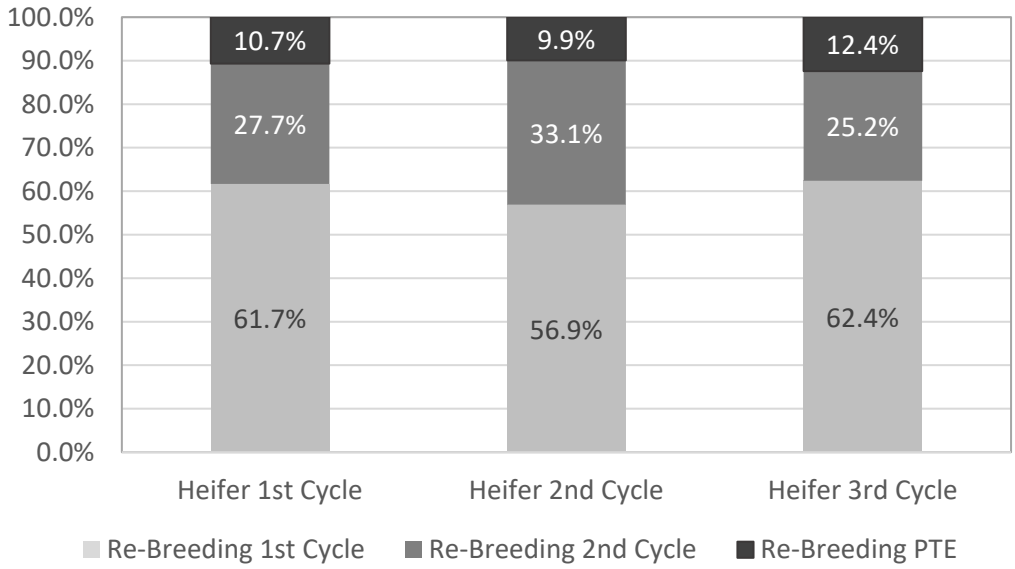

Fig. 1. Re-breeding conception; 1st cycle, 2nd cycle or pregnancy test empty (PTE) for heifer conception cycles 1st, 2nd and 3rd.

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Awareness of breeding ewe management practices by producers with extensive sheep enterprises

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New South Wales rangelands environments are typically based on native pasture systems that experience low annual rainfall (260–404 mm) that is variable both within and between seasons. Tactical grazing where sheep enterprise decision making is dictated by the prevailing season allowing producers to sustainably manage their land resources is commonly used. In these extensive systems, where large paddocks form the basic management units, it can be difficult to implement 'best-practice' breeding ewe management strategies that involve semi-frequent mustering to collect data and actively manage breeding ewes based on their reproductive potential. MLA's Producer Demonstration Site (PDS) program aims to increase the rate of adoption of key management practices and technologies that improve business profitability, productivity, and sustainability. A key focus of the PDS program is to support participating producers to learn new skills and management practices through mentoring and facilitated participatory group learning within their own enterprise. This paper reports the results of a pre-project survey of producers participating in the 'Pregnancy scanning in extensive sheep flocks' PDS project (Hatcher and Broughton 2022). The survey was designed to capture the producers' level of understanding of and confidence in implementing a range of breeding ewe husbandry and management practices.

The four core and seven observer producers completed pre-project surveys in mid-2021. Lamb survival was selected as the primary factor limiting their flock's net reproduction rate (NRR, lambs weaned per ewes joined) in all flocks with ewe fertility, weaner survival and ewe fecundity also identified as limiting factors. Overall, the producers demonstrated a high awareness of key management practices related to breeding ewe performance including target condition scores for ewes at joining and lambing, optimum joining length, time for pregnancy scanning and udder assessment as well as the relative energy requirements of twin- relative to single-bearing ewes in late pregnancy and early lactation. On average, the producers were quite confident of their ability to carry out these practices with average scores of 7.1 to 8.2 for the eight practices (Fig. 1). However, the range in confidence related to assessing ewe condition score, calculating supplementary feed requirements, using electronic ID systems, and making data driven ewe culling decision was large.

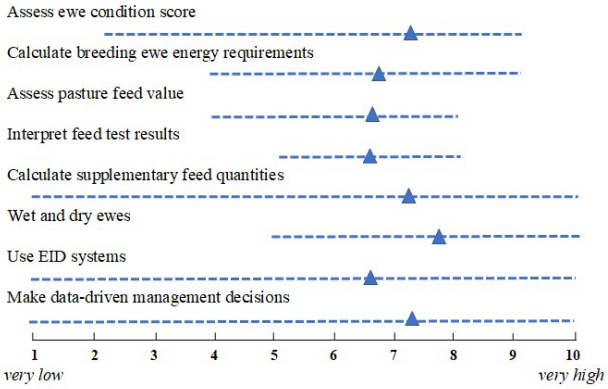

Fig. 1. Sheep producers' self-assessment of the confidence level of their ability to carry out a range of breeding ewe management husbandry and management practices (▲ signifies the average and the dashed line indicates the range).

Interestingly, despite most producers agreeing or strongly agreeing to statements regarding the usefulness of pregnancy scanning for multiples, udder assessment and managing ewe condition score as tools to improve NRR, fewer than half of the producers routinely undertook them as normal practice. The integration of these practices into the routine management and husbandry programs of extensive sheep enterprises may be limiting improvements in NRR. The mentoring and group learning setting provided by this PDS project, particularly the paired comparison of a control (i.e. normal practice) and trial mob undertaken by the core producers, together with the reproduction benchmarking questionnaire (Hatcher and Broughton 2022) and cost-benefit analysis may encourage the wider adoption of these practices in extensive sheep enterprises. A post-project survey will quantify changes in the knowledge, attitudes, skills and aspirations (KASA) of these producers and track their skill development and adoption of key breeding ewe management practices. This PDS will also identify research, development and adoption gaps related to breeding ewe management in extensive sheep production environments.

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Producer demonstration site validates improved productivity of Leucaena in northern Australia

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Leucaena *(L. leucocephala* subsp. g*labrata)* is a palatable perennial legume that is well-suited to beef cattle production systems in northern Australia and offers producers the opportunity to improve productivity and increase carrying capacity. The additional value to an enterprise, from an investment in Leucaena-grass pastures is predicted to be $40 336 per annum for a minimum 30-year period (Bowen and Chudleigh 2018). The development of the psyllid-tolerant Leucaena (var. Redlands) has dramatically increased the potential for the introduction of Leucaena-grass pastures across northern Australia. It is estimated that 26% of cattle properties (4064) and 21% of cattle (3 204 357) occur within the 'ideal' soil and climatic range for Leucaena (Kenny and Drysdale 2019). The introduction of Leucaena into northern grazing systems has the potential to manage feed availability and/or quality and so enable producers to turnoff cattle into supply chains that may be unavailable from unimproved pastures. Previous quantification of the two key adoption drivers for Leucaena (profit and enterprise fit) has focused on cattle operations in central Queensland. This focus on a single cattle-producing region has negatively impacted adoption of Leucaena-grass pastures more broadly across northern Australia. The aim of this project was to quantify productivity and economic benefits from Leucaena into commercial grazing operations in other regions of northern Australia.

Three-year Leucaena grazing trials (May 2020 to May 2023) were undertaken at Goshen Station (Mount Garnet) in the Tablelands region of Queensland and Douglas Daly Research Station in the Top End region of the Northern Territory. The trial at Goshen Station was undertaken using Leucaena (var. Redlands) that was originally established in 2018 with inter-row pasture of Bisset, Rhodes, Urochloa and Buffel grass with Seca stylo. Goshen Station breeds and finishes cattle to a target weight of 450 kg for supply to a local processor. 100 head of Brahman weaners at a stocking rate of 2.5AE/ha on Leucaena and 0.6AE/ha on grass pastures were inducted for the trial. The trial at Douglas Daly Research Station was undertaken using Leucaena (var. Cunningham) established in 1999-2001 with inter-row pastures of Urochloa, Buffel and Pangola grass with Wyn cassia. Douglas Daly Research Station breeds and finishes cattle to 350 kg for the live export market. 84 head of Brahman weaners at a stocking rate of 0.41AE/ha on the Leucaena and 0.39AE/ha on the grass pastures.

To date, cattle on the Leucaena-grass pastures at Goshen Station have achieved an average daily live weight gain of 0.66 kg/d, with an annual live weight gain of 224 kg. Weaner cattle on the grass-only pastures achieved an average daily weight gain of 0.40 kg/d, with an annual live weight gain of 135 kg. Consequently, cattle produced on Leucaena-grass pastures were turned off at 337 d whilst the cattle on the grass-only pastures were turned off at 560 d. In addition, the Leucaena-grass pastures had a carrying capacity four-times that of the grass only pastures. The establishment cost of the Leucaena-grass pastures on Goshen Station was $825/ha with no maintenance costs incurred to date due to the age of the plantings. The Leucaena-grass pastures returned a gross margin of $262/ha compared with $62/ha for the grass only pasture. The change in gross margin (per ha) resulting from the introduction of Leucaena was estimated to be 324%.

Cattle on the Leucaena-grass pastures at the Douglas Daly Research Station achieved an average daily live weight gain of 0.61 kg/d while those on the grass-only pastures achieved an average daily live weight gain of 0.57 kg/d. This correlated to 186 kg and 174 kg per annum live weight gains for cattle on Leucaena-grass and grass-only pastures, respectively. Establishment costs of the Leucaena-grass pasture was $200 per ha with an annual maintenance cost of $72 per ha. The gross margin of the Leucaena-grass pasture and grass-only pasture was $354 /ha and $267/ha, respectively. The percentage improvement in gross margin per ha was estimated to be 32%. The lack of a substantial difference between the two pasture types was unexpected, however previous grazing and management strategies including heavy set stocking, herbicide use and severe Leucaena cutting may have contributed to a reduction in plant numbers and available Leucaena biomass.

The interim trial results demonstrate that introduction of Leucaena improves the economics of cattle production for both local and export markets outside of the Central Queensland region. The results also show that the addition of Leucaena to the production system in a region with suitable soil and climate substantially improves profitability even when Leucaena plantings are relatively mature (20 years old) and climatic conditions favour exceptional grass growth. Future on farm trials will focus on optimum long-term maintenance strategies for Leucaena across northern Australia for sustained productivity.

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Economic analysis of sown stylo and/or grass pastures on red earth and red basalt soils in north Queensland

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The Meat & Livestock Australia funded project, 'Progressing superior tropical grasses and legumes in seasonally-dry Queensland (B.NBP.0812)' is developing strategies for selection and establishment of alternative grass and legume species adapted to diverse soil types and climate zones in north Queensland. The objective of the present study was to conduct an economic analysis of the preliminary results from project B.NBP.0812.

The economic performance of two types of sown pastures for beef production was assessed using a gross margin framework and considered (i) legume stylo (*Stylosanthes* spp.)-grass and (ii) stylo-only, established on (1) red earth (low fertility) and (2) red basalt (high fertility) soil types typical of the Mt Surprise and Charters Towers regions of north Queensland. These scenarios were compared with existing native pastures growing on both soil types. Sown pastures were fertilised with (i) sulphur (red basalt) and (ii) phosphorus and sulphur (red earth) at planting and reapplied every 5 years. Pasture establishment costs were representative of an owner/operator using their own machinery and were included as an annual cost in the gross margin after being amortised over 30 years. The analysis was based on a 100-ha representative paddock, which was used to graze steers from weaning at 6 months to sale at 18 months. North Queensland saleyard cattle prices averaged over the previous 5-years, were applied.

The analysis based on preliminary trial results indicated that investing in stylo-grass pastures was more profitable than stylo-only pastures on both red earth and red basalt soil types in north Queensland (Table 1). Both sown pasture options (stylo-grass and stylo-only) outperformed native, unimproved pastures grown on the same soil type. The high fertility red basalt soil was more profitable than the low fertility red earth soil across all pasture scenarios.

Table 1. Comparison of gross margin results for pastures grown on 100 ha of red earth or red basalt soil types in north Qld

Factor	Soil type and pasture					
	Red earth			Red basalt		
	Native grass	Stylo + grass	Stylo	Native grass	Stylo + grass	Stylo
Livestock sales	$12 119	$45 896	$29 157	$22 047	$73 260	$60 051
Total expenses[A]	$10 432	$35 297	$23 660	$17 535	$47 763	$39 171
Gross margin/annum on 100 ha	$1687	$10 599	$5497	$4513	$25 497	$20 881
Gross margin/annum on 100 ha (after interest[B])	$1253	$9309	$4677	$3780	$23 586	$19 314
Gross margin/ha.annum (after interest[B])	$13	$93	$47	$38	$236	$193

[A]Includes amortised establishment costs.
[B]Interest relates to the opportunity cost of capital. Calculated as the amount of interest that could have been received on the capital invested in the livestock and pasture establishment and subtracting this amount from the gross margin. This allows for an appraisal of the economic worthiness of the investment options by accounting for the earnings foregone by using the capital in this way.

The results of the present study are in accord with previous economic modelling indicating that sown legume-grass pastures can substantially improve the productivity and profitability of beef production in northern Australia (Bowen and Chudleigh 2018; Bowen and Chudleigh 2019, 2021; Bowen *et al.* 2019). However, it is important to recognise that the biological assumptions of pasture and cattle performance applied in the present analysis are yet to be validated at a commercial scale for the study region and soil types. Additional research data measured under grazing conditions will improve confidence in the results of future gross margin and whole-farm economic analysis of these sown pasture options for north Queensland.

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An analysis and comparative study of the growth characteristics and nutritional value of *Desmanthus* (*Desmanthus* spp.) cultivars as a potential silage

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Desmanthus (*Desmanthus* spp.) is a promising improved pasture legume for use across tropical, subtropical and possibly temperate Australia (Gardiner 2016). Since introduction there has been significant investment in the development of new cultivars (McLachlan 2021). Importantly, this includes the Progardes® range, which comprises a large number of newly developed cultivars including JCU 1 (D. leptophyllus), JCU 2 (D. virgatus), JCU 3 (D. virgatus), JCU 4 (D. bicornutus), JCU 5 (D. virgatus), JCU 6 (D. bicornutus), JCU 7 (D. leptophyllus), JCU 8 (D. virgatus) and JCU 9 (D. pernambucanus) (Gardiner 2016; McLachlan 2021). Being tolerable to the northern environment and more importantly heavier textured soils, Desmanthus cultivars can be used to redefine the opportunities for livestock grazing performance (Gardiner 2016). The objective of this study was to analyse and compare six cultivars of the leguminous plant Desmanthus in relation to the selected parameters of growth and development and nutritional quality for potential silage production. This entailed implementation of a greenhouse trial involving nelly bin plots at The University of Queensland Gatton Campus Nursery Facility.

An 8 × 4 factorial experiment was established using a randomised complete block design with four replications. Factor A comprised six cultivars of Desmanthus planted with inoculum (SU 1841) plus two of the cultivars planted without inoculum. The six cultivars were Cv JCU 2, Cv JCU 4, JCU 6, Cv JCU 7, Cv JCU 8 and Cv JCU 9. The two treatments without inoculum were Cv JCU 2 and Cv JCU 6. Factor B was four harvest times (8, 10, 12 and 14 weeks after planting (WAP), when plants were cut to measure yield and nutritional quality. Following harvest plant material was partitioned into leaf, stem and reproductive material and the dry matter yield recorded. Material was then ground and sent to Dairy One™ for nutritional analysis. Two weekly recordings included height, canopy area and the number of stems. Statistical analysis was undertaken used R-Studio and Genstat.

There were significant differences between various cultivars in relation to growth, development and nutritional parameters. JCU 9 recorded the largest height, canopy area, biomass and regrowth production, while JCU 6 recorded the lowest in these parameters. The other cultivars generally were similar and not significantly different from each other. JCU 9 produced a relatively large amount of reproductive material when compared to other cultivars. Stem to leaf ratio was maximised in the 10 WAP harvest throughout the cultivars, except for JCU 9 where the interaction between maturity was minimal. Regrowth production yield following cutting was higher over a shorter timeframe when compared to initial cuttings, where JCU 9 and JCU 8 recorded the highest yields. Cultivars recorded high nutrition, for crude protein, dry matter production, water-soluble and ethanol-soluble carbohydrates and metabolizable energy values, with JCU 6 containing higher nutritive values, whilst JCU 9 was in the lower range. Overall, there was no significant difference between non-inoculated and inoculated treatments for the cultivars tested (i.e. JCU 2 and 6), which is most likely correlated to the addition of fertiliser.

The findings of this study support the preliminary information regarding Desmanthus as a high-quality tropical legume with silage potential. As the trial was conducted under controlled and thus ideal environmental conditions (nutrition, temperature, moisture) the outcomes were likely influenced by these optimum levels and may differ under field conditions. Additionally, when grown under ideal conditions Desmanthus has exhibited capacity to compete with other fodder crops which currently dominate the grazing industry in tropical, subtropical and temperate regions. Particularly in relation to nutrition, yield and also regrowth yields post cutting. While all of the trial cultivars indicated nutritional suitability for silage production, JCU 9 at 14 WAP was the most favourable. This evaluation is based on the nutritive value, although more importantly DM yield which was significantly higher than other samples, thus is favourable for commercial production output. The establishment of field trials across different adaphic and edaphic conditions are now recommended to evaluate the best performing cultivars on a larger scale.

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Student Compendium – supporting the next generation

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In 2021, the Student Compendium was developed by the SA Division of the Agricultural Institute of Australia (AIA) in partnership with the Australian Association of Animal Sciences (SA Branch) and Adelaide University Agriculture Students Association (AUASA). The Student Compendium was originally based on the author's networks and experience over many years of mentoring numerous high school and tertiary students, and national and international early career professionals. It is now a collation of over 150 graduate programs, internships, training opportunities, conferences, competitions, associations, awards and scholarships for South Australian secondary, tertiary and vocational training students undertaking study in agriculture, animal and veterinary science, and agribusiness fields. The Student Compendium is unique and innovative in that it gathers many opportunities that are spread so disparately across numerous websites and locations. The inaugural edition was only available in hard copy for the 60 new student members of the South Australian branches of AIA and AAAS. It is now assisting the next generation of students to find opportunities to engage into agricultural industries and help them develop lifelong, fulfilling careers in agriculture.

For the 2022 edition, three University of Adelaide agriculture and animal science undergraduates were offered remunerated internships with AIA to compile the publication and to expand the scope and reach of the initiative. During their tenure the interns validated each of the compendium's entries published in 2021 and reached out to other organisations to ensure a greater coverage of the range of opportunities that are available for the target audience. They also secured contributions to the costs of development and publication through sponsorship. The 80-hour internships were carried out over the summer break. Students were members of the AIA and had to demonstrate excellent communication skills, an inquiring mind, and a genuine future interest in Agriculture, whether it be research, development, extension or adoption services. An appreciation for rural industry and an interest in understanding issues facing South Australian agriculture were essential. An annual plan was developed by the team, and monitoring and evaluation, engagement and communication and database templates were established. The majority of funding was provided by one major industry partner, and further support was secured through sponsorship and advertising from numerous farming systems groups, businesses and associations.

The internships provided an opportunity for the students to accrue a portion of the compulsory work experience required as a component of their undergraduate studies. It allowed them to gain experience in network building, mentoring, working in a team, project management, grant writing and sponsorship attraction, survey techniques, hard and e-copy resource development and production, and media and scientific conference writing. The internships provided the AIA and AUASA with an opportunity to aggregate and collate important information to prepare the 2022 Student Compendium. It also provided an opportunity for AIA and AUASA to formally work together. This ensured the needs and wants of students were front of mind for AIA, and the Institute was able to gain from new ideas, energy and a fresh perspective to identify and attract future talent.

Since its publication, the 2022 edition has seen 300 hard copies distributed at events and meetings, especially to first year University students. The 'E-copy' of the 2022 Student Compendium is showcased on South Australian Universities Internship and work experience Career Hub E-portals and has been posted on supporting Industry organisations websites.

A critical factor towards the success of this project has been the engagement and alignment of shared values between the AIA and the AUASA Executive. AIA invited the Chair of AUASA and a 2nd year representative to sit on the AIA-SA committee for professional experience, and together identified and developed collaborative events, activities and resources. This led to AIA's subsequent and successful engagement of the three student interns. During an evaluation focus group session, students indicated that 'it was highly valued and they appreciated the diversity and the exposure to many opportunities and it gave them new ideas on potential careers they hadn't previously thought of, and they hoped this partnership grows in future years'. Also, some early career professionals who sighted a copy have repeatedly indicated 'I wished I had it during my undergraduate days'.

Based on interest and feedback received since the publishing of the Student Compendiums in 2021 and 2022, and as more people hear about it via personal communications, mass media, and as new organisations and sectors are approached by the interns and AIA-SA alike, more businesses are choosing to contribute editorial content, and some are favouring funding and sponsorship. It's an innovative and unique centrepiece resource that is a talking piece and conversation starter to 'call everyone to action' on all of the building human capacity pillars of SA Sheep, Beef and Grains Industry Blueprints. The Student Compendium will continue to assist the next generation of students to find opportunities to engage and be attracted into agricultural industries and help them along on their life long, full-filling careers in agriculture.

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Available at https://livestocksa.org.au/industry-development/industry-blueprints
Available at https://blueprint.grainproducerssa.com.au/

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Improving Merino sheep reproductive performance in the NSW rangelands

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Pregnancy scanning is a key enabling component of a suite of management interventions that can increase the net reproduction rate (NRR, lambs weaned per ewes joined) of sheep flocks (Young *et al.* 2016). These interventions include differential nutritional and lambing management of single and twin-bearing ewes and informed ewe culling and selection decisions. These interventions were developed in high rainfall and mixed farming regions and are increasingly being used in those regions to actively manage breeding ewes. The applicability of these interventions to improve NRR of sheep enterprises in the NSW rangelands is unknown. Rangelands enterprises typically have large paddock sizes, difficulty specifically targeting the nutrition of twin-bearing ewes and extended joining periods, compared to the high rainfall and mixed farming regions. This paper presents the average reproductive performance of four rangelands sheep enterprises for five seasons before the start of a three-year Producer Demonstration Site (PDS) project (Pregnancy scanning in extensive sheep flocks). The aim of the PDS is to demonstrate that pregnancy scanning for foetal number together with wet and drying ewes at marking can be used to optimise breeding ewe management, identify and retain ewes with proven reproductive performance and increase the NRR of extensive flocks with extended joining periods.

A key component of the PDS is collecting a comprehensive suite of reproduction data from producers undertaking an on-farm mob comparison. A benchmarking questionnaire was designed to capture property, sheep enterprise, and general flock husbandry details and the past performance of the sheep enterprise. The past 5-year performance (maiden and adult ewes) comprised the number of ewes joined, ram percentage, pregnancy scanning results, lambs marked, lambs weaned and ewe mortality. General comments and seasonal conditions were also recorded. The four properties are located within the western Riverina (between Hay and Darlington Point) and Western NSW (north of Wentworth and west of Wilcannia). Average rainfall is winter dominant, low (260–404 mm across the four properties) and highly variable. The total area of the properties ranges between 7900 to 64 409 ha with 96–99% of the total area available for grazing and an average paddock size from 450 to 2832 ha (Table 1). The smallest of the flocks has 3052 breeding ewes and the largest 30 000 with stocking rates between 0.12 to 0.58 sheep per hectare.

Table 1. Total area (ha), average paddock size (ha) standard reference weight (SRW[A], kg), breeding ewes (hd), average NRR (%) and average ewe mortality (%) for four extensive sheep properties in western NSW from 2016 to 2020

Property ID	Total area (ha)	Ave. paddock size (ha)	SRW (kg)	Breeding ewes (hd)	NRR (%)	Ewe mortality (%)
1	31 504	450	60	3865	45.9	2
2	64 409	2832	65	7335	47.0	11
3	7900	718	55	3052	47.7	Unknown
4	52 000	1500	70	30 000	77.8	3

[A]SRW is the liveweight of a mature, bare shorn, dry ewe in condition score 3.

Each of the properties experienced dry to drought conditions for most of the past five seasons. The number of ewes joined was reduced in three of the four flocks. Containment areas (fenced sections of a property where stock are lot fed) were used to maintain numbers in the fourth flock. In 2018, one property did not join, and another joined only after late rain and lambed during summer in less-than-ideal conditions. Poor conception rates occurred twice in one of the flocks following atypical summer rainfall negatively impacting ewe performance. The 5-year average NRR of the four flocks ranged from 45.9% to 77.8%, with ewe mortality between 2% and 11% (Table 1). An important outcome from collating and reporting the past performance of the four flocks was identifying that some key sheep reproductive data was not collected. In situations when key husbandry events coincide, like shearing and weaning, weaner numbers were not recorded due to a lack of labour. Where data was collected, it was not always stored in a format easily accessible for analysis and year-to-year comparison of flock reproductive performance. The benchmarking process has highlighted the need to develop data capture processes for sheep reproduction data to identify underlying issues and monitor the impact of new management practices. The four properties have each selected a control and a trial mob and will commence a paired comparison of reproductive performance for two breeding cycles starting with a six- or seven-week joining in late 2021 or early 2022.

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We gratefully acknowledge Meat & Livestock Australia for funding this Producer Demonstration Site and the sheep producers involved. This project is run in collaboration with MerinoLink Limited.

Remediation of dam by-wash with rock chute in central Queensland

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The Reef Protection Regulations in Queensland require graziers to document property areas of low land condition and make a plan for their future management (DES 2021). The Grazing Resilience and Sustainable Solutions (GRASS) program, funded by the Department of Environment and Science (DES), assists graziers in Great Barrier Reef catchments develop Action Plans for Land Management (APLM) for these areas and offers specialist support for issues such as erosion control. A grazier in the Fitzroy region identified significant erosion on a dam by-wash (Fig. 1a) and engaged the Department of Agriculture and Fisheries (DAF) extension staff to assist with development of an APLM and a detailed plan for restoration of the eroded area. The aim of this project was to work with the landholder to reduce sediment loss from a gully created by the dam by-wash.

DAF staff engaged a soil conservation consultant to design an erosion mitigation strategy for the landholder. The site was located on a beef cattle property at Thangool, central Queensland, with Brigalow softwood land types consisting of alluvial, self-mulching topsoil and dispersive clay subsoil. The potential volume of water passing through the erosion site from rainfall events of different durations and intensities was determined by catchment size, elevation, vegetation, and infiltration rates using the Empirical version of the Rational method as described by Day and Shepherd (2019). Initial calculations using the Ramwade flow calculator tool (Carey *et al.* 2015) showed that the 190-ha catchment had a 1% slope at the gully erosion site. A rock chute structure was designed to handle a peak water flow of 20 m^3/s expected from a 1 in 50-year rainfall event in the catchment.

The rock chute design specifications included a 35 m chute crest around the top of the gully, a batter of 3:1 through the gully head, a 6-m chute batter and an apron length of 2 m and depth of 0.3 m to dissipate the water turbulence. Earth moving at the site began with shaping the level crest and batter, then excavation of 0.6 m deep cut off trenches around the chute crest and at the end of the apron. Excess soil from the shaping and battering of the chute was used to construct a diversion wing bank to direct water over the rock chute. Geofabric was laid across the top cut off trench and the top of chute batter. The geofabric was keyed in underneath a layer of compacted gravel and 600 mm quarry rock. A wire netting fence was erected at the bottom of the rock chute to hold rock in place and catch debris to further stabilise the site.

The rock chute was completed on 21 July 2021 and 402 mm of rainfall was received at the site from completion to 28 February 2022. Visual site assessments indicated very limited sediment movement at the apron of the rock chute (Fig. 1b).

Fig. 1. Erosion at the dam by-wash prior to rock chute construction (a) and the completed rock chute (b).

Calculations of sediment saving based on the rate of erosion at the site estimated that approximately 150 tonnes of sediment would be prevented from running off into the Fitzroy River catchment annually. Over time, more pasture growth around the rock chute site will help to further strengthen the structure and increase its ability to handle extreme rainfall events. In conclusion, the construction of the rock chute has reduced the risk of sediment runoff from a heavily eroding dam by-wash. The project has allowed the land holders to engage with extension staff and consultants through participation in the GRASS project and successfully demonstrate the proactive measures undertaken to be compliant under reef regulations.

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Insights on publishing papers

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One of the critical aspects of undertaking research is the dissemination of the outcomes, firstly in the scientific press, paving the way for wider dissemination to industry and adopters. After extensive experience as an Editor with several journals and most recently as the Editor-in-Chief of the international journal *Meat Science* for the past 9 years, I have observed that there is a real need for scientists and their students to be better informed and taught about how to achieve the goal of scientific publication. To this end I recently published a paper to aid authors to increase the chances of publishing their research (Hopkins 2022), based on an invited presentation at a conference in Serbia in September 2021. This drew on extensive experience in publishing papers as an author (more than 650 papers including 34 review papers) and the insights gained from being an active Editor-in-Chief overseeing the evaluation of more than 9,000 papers for *Meat Science.* Often editors act as gate keepers without careful consideration of the papers assigned to them for evaluation, but by screening every paper submitted to *Meat Science* it has provided real insights as to the reasons why papers fail to get published. These will be outlined here with the sole purpose of attempting to help authors navigate the publication process. This is very important for several reasons: (1) failure to publish lowers the return on Research & Development investment; and (2) failure to publish impacts on careers. If you take *Meat Science* as an example with approximately 20% of submitted papers never published anywhere and given on average the journal receives 1000 papers per year this means the content of approximately 200 papers never sees the light of day. Apply your own estimates of what this might add up to in fiscal terms and either way it is a significant cost, with no return.

In assessing the results of 1000 papers submitted to *Meat Science* from July 2020 to June 2021, the most important reason for rejection was papers were outside the scope of the journal. Over this period this represented over 30% of the papers and this is a consistent trend over the years. This is an easy issue to address if authors consult the journal scope and students are trained to do the same. If authors are unsure whether their paper will fall within the scope they can always contact the editor or help section of a journal.

Over the same time more than 25% of papers were also desk rejected after evaluation and the most common reason for this was flawed experimental designs. This could include the absence of replication, a frequent error in the evaluation of processed meats, feeding studies again with no replication as group feeding is often applied with only one group per treatment and a lesser number of studies where ‘breeds’ were compared with no data on the genetic spectrum of the sires provided or where inadequate numbers of sires were represented. Related to these issues is a significant number of papers where no statistical models are outlined and statements like ‘an Analysis of Variance was used’ are made to indicate how the data were analysed! This problem extends often to the exclusion of all the relevant fixed and random terms and on occasion the absence of interaction terms, with the former aspect frequently observed in the analysis of sensory data. Other papers are rejected for excessive overlap with other published studies. Authors need to be aware that all papers in reputable journals are screened to detect overlap with other sources of text and duplication with previously considered papers. If excessive levels of overlap with other texts are detected, then a manuscript will be automatically rejected if the paper is not authored by any of the current authors. If there is overlap with previous papers of the author(s) in areas like the methods this can be reduced by referring to previous papers provided they clearly give all the required detail. After undergoing the full review process approximately 20% of papers were still rejected by *Meat Science* and aspects such as lack of novelty and inappropriate methods were some of the reasons. Students must be reassured if they have a paper rejected, it can be used as a learning exercise and thus must be reminded that it happens to all scientists! If authors do manage to get their paper through the review process and are requested to undertake revisions, it is really, important that each point raised by the reviewers is dealt with in a systematic way and modifications are made as required, but if you disagree with a reviewer provide a scientifically solid rebuttal.

In summary, editors are looking for the following: papers in the scope of the journal; originality; robust designs; new knowledge; use of appropriate methods; readability; and studies that meet ethical standards. In terms of the papers themselves, ensure you submit to an appropriate journal and only to one journal at a time, pay attention to journal requirements and the structure of the papers they publish, check the grammar, seek colleagues to proofread your papers and be self-critical by allowing ‘sitting time’ before you submit. This last point allows authors to read their papers with fresh eyes and this will often pick up errors that the brain has missed because of familiarity with the text.

If you have questions or are not clear about something in the publication process you can always email the editor for the target journal. Additionally, I run seminars/webinars for staff and students on how to publish with some practical exercises to teach about correct experimental design. This can also include how to write a review paper. Contact me if you wish to take up this option.

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Targeted industry engagement was 'spot-on' for pasture dieback

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Pasture Dieback (PD) is a condition that has been sporadically affecting sown pasture production in high rainfall zones of eastern Queensland for about 100 years. In recent years, there has been a large increase in the pasture species and area affected by PD. Affected pastures display progressive symptoms of stress which results in otherwise unexplained death, during what should be high growth periods. Currently, pathogenic organisms are the focus of multiple diagnostic research projects (Buck *et. al* 2021). Our objective was to increase graziers' capability to accurately identify PD and implement appropriate management practices by conducting an industry engagement program.

A multi-faceted extension strategy was delivered by the Department of Agriculture and Fisheries (DAF) across eastern Queensland from August 2020 to November 2021 and included developing an industry network, fact sheet series, face-to-face extension, management plan templates and online information services. The Pasture Dieback Industry Network (PDIN) was established (August 2021) to enable those interested in PD to receive updates about the latest outcomes of research trials and upcoming events via email newsletters. Recipients were also directed to PD information on FutureBeef website pages. Project staff presented at a variety of industry events including seminars, meetings, webinars, TV interviews, and newspaper print and e-articles. Additionally, a targeted series of extension events were held including forums, paddock walks and workshops. In total, project staff participated in 33 industry engagement activities. The most recent extension events, Pasture Dieback Management (PDM) workshops, assisted graziers to work through management options for PD on their property through an interactive process using planning templates. Nine workshops were conducted in 8 locations in the PD-affected areas of eastern Queensland. These workshops included: peer to peer group learning activities, brief scientific research updates, practical recommendations to encourage practice change, and follow up information and services to enable adoption. Workshop content included four best-practice management options for areas affected by PD; manage for recovery, improve the pasture, plant a break crop and treat a pathogen. Participants discussed their planned management strategy as a group activity. Feedback sheets were collected at the conclusion of each workshop.

As a result of the extension program, 297 stakeholders voluntarily become members of the PDIN. For the six PDIN newsletters delivered there was, on average, a 69.6% open rate and a 20.2% click rate, which is 46.3% and 17.3% higher than the industry average, respectively (Mail Chimp 2019). Since the development of the PDIN, PD information page views on the FutureBeef website (www.futurebeef.com.au) increased from 4,011 to 9,706. Fourteen DAF-lead face-to-face extension events were attended by a total of 317 graziers who collectively manage 1.57 million ha of land. Feedback from the PDM workshops indicated a high average overall usefulness of the day (6.4 out of 7). Three quarters (75%) of respondents said they intended to make a change due to the workshop and the likelihood to do so was an average of 6 out of 7. There was an improvement in the understanding of 5 key workshop concepts that addressed the aims of the project (Table 1). The greatest improvement was for understanding 'successful management solutions.' The PDM workshop group activity indicated that most producers intended to either manage for recovery or improve the pasture.

Table 1. Average score of knowledge and understanding of concepts before and after Pasture Dieback Management workshops for 115 respondents[A]

Concept	Average score for knowledge and understanding		
	Before	After	Change
How dieback is affecting pastures in the local area	3.7	5.7	+ 2.0
How to identify pasture dieback	3.7	6.0	+ 2.3
Potential casual factors of pasture dieback	3.3	5.7	+ 2.4
Whether pastures can recover from dieback	3.4	5.8	+ 2.4
Successful management solutions	3.0	5.7	+ 2.7

[A]Rating scale: 1 = very poor knowledge and understanding; 7 = very good knowledge and understanding.

Industry engagement activities conducted under this project have demonstrated an improvement in graziers' ability to accurately identify PD and develop a management plan for affected areas. It is recommended that future work be conducted to support producers to enact their management plans for PD.

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We acknowledge the co-funding provided by Meat & Livestock Australia.

Producer survey results used to direct extension efforts and increase adoption in south west Queensland: a GrazingFutures case study

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GrazingFutures (GF) is an extension project funded by the Queensland Government and the Drought and Climate Adaption Program focussed on improving business management and drought resilience of extensive livestock producers in western Queensland. Western Queensland has a highly variable climate and since 2013 the south west has been subject to almost continuous drought declarations (Bowen and Chudleigh 2021). Despite these prevailing drought conditions graziers have successfully implemented practice changes supported by GF that have better equipped their businesses to prepare for, respond to and recover from drought (Rolfe *et al.* 2020). A small sample of south west Queensland producers were surveyed, with the objective of the survey to provide insights from producers, known to have made a recent practice change, so the GF team could direct their extension efforts and improve adoption of recommended practices.

Eleven graziers from six properties were surveyed on property in person by GR Consulting in 2021. These graziers reflected upon the practice changes they had made within their businesses and the resources they used when considering and implementing the change. The qualitative surveying method was designed to allow producers to provide their responses in an in-depth conversational manner. Five topics were focused on in the survey: (1) sources of support when changing a practice; (2) service provider support other than workshop type activities; (3) business management skills; (4) drought preparedness; and (5) early weaning. The below results focus on two of the surveyed topics, business management and drought preparedness because of their relevance to grazing business success in the Australian rangelands.

All graziers surveyed rated business skills at the highest rating of 'Very important', often describing them as critical to their business's success. Furthermore, all producers said they would like to receive more support to build upon their current business skills. A skill referred to was to better understand and use information in their business activity statements (BAS) to learn more about their businesses financial position. Other skills were bookkeeping, payroll management, and financial planning. The skills that these producers were seeking were indicative of their challenges in business management. Half (50%) of the properties surveyed said they found no aspects of business management to be holding their business back. That indicates at least 50% believe their current business capabilities hold them back.

When asked about drought preparedness, only 50% of the businesses surveyed rated themselves as well prepared for drought with the remaining 50% rating themselves as poorly prepared or not prepared at all. The level of preparedness was rated on a scale of 1 (not at all) to 10 (very much), with a rating of >7 being the marker level of a practical standard of drought preparation. The topics mentioned as most critical for being drought prepared included having finances in order and available, being able to realistically manage available feed as well as improvements in property infrastructure. Five of the six businesses commented that they wanted to be better prepared for future droughts by changing aspects of their previous drought management, these changes correlate with the topics listed above. Surveyed producers were asked what support could be provided by service providers to assist when implementing practice change. Providing new information on management topics and technologies was mentioned most, followed by ongoing support or follow-up after the event was completed.

The GF project team have used these report findings to direct extension efforts in two main ways. Firstly, the team is focussing efforts on delivering follow-up to graziers, rather than holding additional events, as a method to deliver new information and support practice change. Planned follow-up methods include phone calls, face to face and small group sessions. Event numbers have been reduced and appropriate time has been allocated in formal workplans to ensure follow-up is completed. Secondly, business literacy skills are being prioritised as well as the continuation of already established business groups, with plans to deliver information on bookkeeping, interpreting BAS, and payroll management. Whilst the sample size of these surveys was small, the results offered relevant local leads which were used to inform the GF approach to support on ground practice change. It is recommended that similar surveys should continue in the future to help direct project efforts and improve adoption of practice change.

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This work was funded by the GrazingFutures Livestock Business Resilience project, which improves drought preparedness and viability of Queensland livestock producers and is jointly funded by the Australian Government's Future Drought Fund and the Queensland Government. We also acknowledge Gerry Roberts (GR Consulting, Longreach) for his assistance in compiling this abstract.

Improving land condition on grazing properties in the Burdekin to improve reef water quality

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The majority of the fine sediment that reaches the Great Barrier Reef (GBR) is attributed to grazing practices (Koci *et al*. 2020), as historical grazing pressure and pasture overutilization in the region has resulted in widespread degradation, including gully formation, hillslope and streambank erosion (Dunn *et al.* 2010). There has been significant financial investment across the Burdekin region to encourage landholder adoption of sustainable grazing practices, through provision of training and education for graziers in the region and financial incentives to implement grazing land management changes. NQ Dry Tropics is an independent, not-for-profit Natural Resource Management organisation focused on assisting graziers to implement practice changes that improve local land condition. Land condition is measured using an A-D scale, where A is the highest possible land condition score, and D is lowest. The main objective of practice change is to move land condition from a lower score (C or D) to a higher score (B or A) by increasing groundcover in degraded areas. NQ Dry Tropics helps to achieve this by assisting graziers in improving management practices to aid in the recovery of grazing land.

Increasing groundcover on grazing properties is an important first step in improving land condition and minimising the amount of sediment that is washed into waterways feeding the GBR, particularly at the start of the wet season. NQ Dry Tropics field officers use a variety of tools to identify high-priority areas such as topography, soil types and end of dry season groundcover imagery, which is captured by satellite. This imagery can be particularly useful to demonstrate areas on graziers' properties which are over-utilised, often drawing a stark comparison between these areas and areas which are under-utilised. Imagery used by NQ Dry Tropics staff uses a red-green scale wherein the 0% groundcover shows red and 100% groundcover shows dark green. Graziers are generally aware of the habits of their livestock, however being able to clearly visualise the difference between areas preferred by cattle also helps them with decision making and can prompt more effective extension engagements.

NQ Dry Tropics staff also make use of the Paddock to Reef Projector Tool, which estimates the possible sediment saving from practice change across a source-catchment. The projected sediment saving is generally modelled using stream order, sediment delivery efficiency, catchment topography, soil type, ground cover and the nature of the practice change(s). Practice change questions determine how much sediment may be saved based on moving from a lower rated grazing practice to a higher one (i.e. C to B). Having the projector tool available better assists staff in targeting higher sediment-yielding areas and prioritising investment. Furthermore, being able to see areas which are more prone to degradation can help prompt graziers to undertake projects in these higher priority areas to improve their land condition and future production potential. The overall aim is to increase the end of dry season groundcover and reduce sediment runoff into riparian systems.

The results of a survey sent out to graziers in January 2021 confirmed that most graziers prioritise increasing their pasture quality and quantity, as well as increasing pasture species diversity. These goals align closely with targets to improve pasture condition and achieve a significant reduction in fine sediment loads to the GBR. A high proportion of Burdekin graziers are open to extension engagement and NQ Dry Tropics field staff are able to assist them to develop projects that can achieve significant practice improvements. Survey results also indicated that graziers value the opportunity for extension services and training, and many graziers also highlighted concerns surrounding erosion and the degradation of landscapes.

Identifying Burdekin graziers' goals for property improvement and landscape remediation allows extension officers to provide tailored opportunities and targeted financial incentives to assist these graziers in achieving their goals sooner than they otherwise would. Graziers are offered opportunities to improve their skills and capabilities in all aspects of their grazing enterprise, whether it be business, herd or pasture management. This holistic approach encourages a philosophy of continual improvement which results in ongoing benefits, increased productivity and profitability as well as an improvement in water quality and sustainability values. This results in an ecological benefit for the local environment as well as improved water quality in surrounding catchments and the GBR. Equipping landholders with the skills they need to build a resilient and viable grazing operation also helps improve the sustainability of the Australian agriculture industry collectively, ensuring the longevity of family businesses and local communities.

In conclusion, graziers are open to practice change and by offering accessible and tailored support services, extension officers can assist Burdekin graziers in achieving this. Being able to take advantage of the range of tools and opportunities available also allows NQ Dry Tropics to more effectively and efficiently engage with graziers and be able to streamline processes to reach a common goal. This ensures that the dual benefit of long-term business viability and an improvement in landscape health is reached, helping the grazing industry in the region to remain sustainable for future generations.

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What's hatching in training and extension in the Australian chicken meat industry

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The Australian chicken meat industry contributes over $2.8 billion/year to the economy and directly employs more than 58,000 people. Including approximately 720 contract chicken growers. The percentage of total chickens slaughtered in 2020 (663 873 900) by state was NSW 32%, Vic 20%, Qld 20% and SA, WA and Tas combined 28%. Baiada Poultry and Inghams Enterprises supply approximately 70% of Australia's meat chickens (Australian Chicken Meat Federation). The objectives of the *Training and extension for the Australian chicken meat industry* project is to develop and provide ongoing extension and training for the industry. The project is focused on delivering outcomes of AgriFutures Australia research and development (R&D) projects, improving engagement with industry and adoption of research, and developing a national training framework. The project is funded by AgriFutures Australia and delivered by the Department of Agriculture and Fisheries. This paper summarises some of the project highlights to date.

Outcomes and outputs of R&D projects are delivered through various methods including industry webinars, newsletters, facilitating the development of industry tools from R&D, fact sheets, the *Chicken meat RD&E* website, YouTube and podcast channels. An initial scoping study of national and international training providers, materials and activities combined with industry and training provider interviews led to the development of a training needs survey, an online interactive animal welfare training pilot and online biosecurity training activity. The project team consult regularly with the Chicken Meat Advisory Panel which is also the project steering committee.

Project highlights to date include the: national training needs survey, animal welfare training pilots, development of an online biosecurity training activity, industry webinars, *Research RoundUp* newsletter, *Chicken meat RD&E* website, and online *Poultry legislation search tool*. A national chicken meat industry training needs survey for growers, breeder and hatchery managers, livestock service managers and veterinarians was conducted in 2020. The responses provided valuable insight into industry wide training priorities and preferred delivery. The top three topics identified by growers were (i) ventilation, (ii) work health and safety, and weighted equally at (iii) biosecurity planning | brooding | health and diseases | litter and spent litter management. A similar survey for chicken meat processors is planned for 2022. Two online, interactive animal welfare training pilots were developed and delivered by 4 Up Skilling Pty Ltd in early 2021. Feedback from both pilots was positive and will help inform future training activities. An online training activity *Introduction to farm biosecurity for chicken growers* was also developed and is currently being reviewed by industry.

The 12 industry webinars held to date have showcased 30 AgriFutures projects by 25 individual presenters, had 1407 registrations (6–21% from overseas) and 791 participants (i.e. a 56% average attendance rate). The topics covered include litter management, nutrition, gut health, water and energy, environmental sustainability, biosecurity and bird behaviour. Webinar poll results from 2021 show that on average 41% of respondents found the information very useful, 47% found it useful, 52% are likely and 26% very likely to use the information in their business, and 100% are interested in attending more webinars. *Research RoundUp* is a targeted selection of recently published journal articles related to chicken meat production. It is emailed monthly to over 100 subscribers, predominantly researchers and company staff. A subscriber satisfaction survey is currently underway. The *Chicken meat RD&E* website was refreshed in 2020 and there has been a positive trend in website metrics since. In 2021, there were 6309 pageviews by 2506 users of the site – a 154% increase in the number of users, a 108% increase in sessions and a 50% increase in pageviews from 2020. The *Poultry legislation search tool* pulls together the various legislation, standards and guidelines related to biosecurity, animal welfare and food safety for the chicken meat industry into a single, easy to search location. Published in October 2020, the tool had 296 page views and 273 unique pageviews in 2021. Two more new online tools are in development.

While not a replacement for face-to-face engagement and activities, the online delivery of information, tools and training via electronic methods has been well received. It provides additional options for people to access information, tools and researchers. Opportunities to improve the project include clearly segmenting our client groups, gaining more direct feedback from them, and implementing ongoing feedback loops. There are also opportunities to better communicate and promote these options, plus increase the number and type of offerings consistent with client feedback (Coutts J&R). COVID's restrictions have been challenging and we are all looking forward to being able to meet and work together in person more.

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Alternative management strategies for Central Queensland beef business

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The profitability and resilience of Central Queensland (CQ) beef enterprises is affected by the management strategies that are used in response to property level production implications (Bowen and Chudleigh 2018). Therefore, when assessing the relative value of a current or potential new management strategy, it is critical to apply a sound economic framework at a property level basis. The aim of this study was to use an established farm-management economic framework to assess the benefits of implementing two alternative management strategies on a CQ case study herd: (1) correcting a phosphorus (P) deficiency through wet season supplementation; and (2) modifying the turn-off age of male cattle from bullocks to feedlot entry weight (Bowen and Chudleigh 2018).

The Breedcow and Dynama herd budgeting software (Holmes *et al.* 2017) was used to analyse two management strategies for a self-replacing breeding and finishing herd of 137 cows, located 30 km north of Rockhampton. The 1037-ha property is dominated by Blue and River red gum flats and Goldfield's red soil land types which are considered to be low in P status (State of Queensland 2019) and marginally P deficient for cattle as per definitions of Bowen *et al.* (2020). The existing base herd was supplemented during the wet season with a liquid supplement containing 1.5% P, considered to be inadequate to meet the herds P requirements. The marketing strategy was to grow steers on the more productive and P adequate alluvial land types and market to Teys Australia abattoir (Rockhampton, Qld) as finished slaughter steers >580 kg liveweight (LW). Assumptions used to model the alternative strategies were as follows. Strategy 1 replaced the current liquid supplement with a dry lick ration of 80% Kynophos® and 20% salt for 90 days in the wet season, and increased cow conception rate by 5% and cull cow LW by 10 kg. Strategy 2 marketed steers to CQLX Gracemere saleyards (Rockhampton, Qld), as feeder steers at 350–450 kg LW range. The price basis for each class of livestock was derived from CQLX Gracemere saleyards data and Teys Australia Abattoir (Rockhampton, Qld) average prices over a 6-month period between September 2020 to February 2021.

Strategies 1 and 2 resulted in an extra $8333 profit/annum and $17 606 profit/annum respectively, which were 6.85% and 14.5% higher than the existing base case study herd. Altering the P ration in Strategy 1, to adequately address the P deficiency, reduced the husbandry costs by $7050/annum and the increase in conception rate decreased the breeder numbers from 137 to 128 head. Strategy 2 reduced the steer maximum age of turn-off from 48 to 36 months, which increased breeder numbers to 167 head and resulted in husbandry costs increasing by $1498/annum.

Our study demonstrated that both Strategies 1 and 2 were more profitable than the base case study herd. The increase in profitability is consistent with the work reported by (Bowen and Chudleigh 2018; Bowen *et al.* 2020). However, in terms of business resilience, changing to a feeder steer marketing strategy increased drought risk due to the higher proportion of breeders in the herd (Bowen and Chudleigh 2021*a*, 2021*b*). In comparison, replacing the high-cost supplementation with a P adequate ration in Strategy 1 provided the benefit of decreased drought risk, but with a significantly smaller profit/annum. By using the established framework, the study has identified comparable benefits and disadvantages of implementing both strategies in isolation. It has however, been demonstrated by Bowen and Chudleigh (2021*b*) that modelling strategies in isolation may not identify the complementary or the additive benefits of implementing strategies simultaneously. It could then be expected that if Strategies 1 and 2 are implemented simultaneously, an increase in profit/annum and only a marginal increase in drought risk may be achieved through the complementary benefits of implementing both Strategies. It is recommended that the producer implement both Strategies 1 and 2 and change the steer age and weight of turn-off to a maximum (36 months, 450 kg) and replace the existing wet season supplementation program with a P adequate supplement.

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Profit drivers for Queensland dairy farms 2015–16 to 2020–21

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In 2020–21 Queensland produced 309 million litres of milk which has declined from a high of 848 million litres in 1999–2000. The decline in production has been caused by an exodus of dairy farmers from the industry due to reduced profitability and increased risk.

This paper examines the profit drivers for Queensland dairy farms, using Queensland Dairy Accounting Scheme (QDAS) data. In particular, the relationship between profitability and total farm production and production per cow is examined. QDAS was established in 1976 and examines the cashflow, profitability and production efficiencies of Queensland's dairy farms. In 2020–21 data was collected from 52 farms, which represents 28% of Queensland's milk production (Murphy *et al.* 2021). The key measure of profitability in QDAS is Earnings Before Interest and Tax (EBIT).

Six years of QDAS data was examined, from 2015–16 to 2020–21. In these years the average EBIT per cow ranged from $758 in 2016–17 to a low of $113 in 2018–19. Fig. 1a shows the 325 data points for EBIT per cow and total farm production, with a linear relationship ($R^2 = 0.1794$) between the two factors showing that as farm production increases so does EBIT per cow. Fig. 1b shows the 325 data points for EBIT per cow and production per cow, with a linear relationship ($R^2 = 0.1419$) between the two factors showing that as production per cow increases so does EBIT per cow.

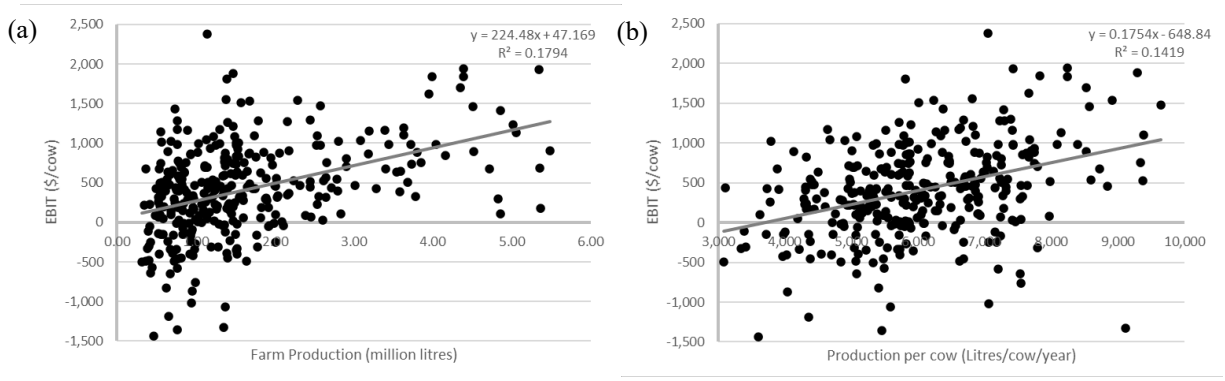

Fig. 1. The relationship between (a) EBIT ($/cow) and farm production and (b) EBIT ($/cow) and production per cow.

The expected explanation of the positive relationship between EBIT per cow and total production is the effect of economies of scale and the dilution of overhead costs. While this is partly true, over the past 20 years as farms have grown and the risk associated with larger operations has increased, only the better farm managers have made profits (Murphy *et al.* 2021). Those farms with poor farm management who have increased production have ceased operating. Smaller farms with poorer management can compensate by using family labour to maintain a sufficient cashflow to survive.

Farms with consistently higher than average EBIT feed a balanced diet, have a calving interval close to 12 months and rear large and healthy heifers ready to produce milk. These three characteristics all lead to high production per cow and explains the relationship between production per cow and EBIT.

Other drivers of profit include cost control, capital efficiency and labour efficiency. Cost control, especially in large farms, is achieved with forward purchasing feeds and, in some cases, informal cooperative purchasing with other farmers. Capital efficiency is achieved by having reliable equipment of the appropriate scale. Finally, labour efficiency is achieved by farms having efficient systems that allow labour to be productive which allows managers to manage the business rather than work in the business.

The most important driver of profit is the hardest to measure, management skill. The farm managers in QDAS with consistently above average EBIT have good people skills, undertake timely farm management actions, are always looking to improve their farm systems and performance and have a positive attitude.

In conclusion, the positive relationship between production per cow and EBIT per cow is due to the good managerial skills of the farm managers. The positive relationship between total production and EBIT per cow is due to those good managers who increase production by increasing cow numbers and production per cow have been resilient, while those with less skill who have increased production by only increasing cow numbers have often left the industry.

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The Grazing Resilience and Sustainable Solutions project provides extension support for improved land management in the Fitzroy region of Queensland

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The Grazing Resilience and Sustainable Solutions (GRASS) project was developed to assist graziers across the Burdekin, Fitzroy and Burnett Mary River catchments of Australia to comply with Reef Protection Regulations which are a part of the Queensland Reef Water Quality Program (QRWQP). To be compliant, the regulations state that landholders must maintain land with over 50% ground cover at the end of the dry season (30 September) every year. Land in condition 'C' or 'D' is to be documented and have a plan made to halt the degradation, or improve the land condition (DES 2021). The GRASS project is delivered by the Department of Agriculture and Fisheries, Queensland (DAF) in partnership with Natural Resource Management (NRM) groups NQ Dry Tropics, Fitzroy Basin Association (FBA) and the Burnett Mary Regional Group (BMRG). The overall objective of the GRASS program is to work with individual graziers to develop an Action Plan for Land Management (APLM) documenting the intended management of land in C or D condition to halt or repair degradation, or the continued good management of land in A or B condition. The aim of this paper is to report the key achievements of the DAF grazing extension support activities in the GRASS project including the number of completed APLMs.

The GRASS project was delivered October 2019 to June 2022. DAF extension teams worked with graziers to support the improvement of land management through one-on-one extension, development of APLMs and funding support for on-property incentives such as small-to-medium scale gully remediation, riparian and hillslope fencing. DAF's extension targets included 15 APLMs in both the Burdekin and Fitzroy catchments and 16 APLMs in the Burnett-Mary catchment, each financial year. Actions from APLMs have been used to calculate sediment saved from run-off using the Paddock to Reef (P2R) projector tool (Paddock 2 Reef 2020). Upon completion of APLMs, landholders were issued with a letter acknowledging participation in the GRASS program and the prescribed land management actions.

From October 2019 to June 2021, the DAF extension officers worked with landholders to complete 138 APLMs, exceeding the target by 71%. Actions detailed in the APLMs have contributed to a decrease in 1600 tonnes of sediment run-off into the Great Barrier Reef lagoon. Actions include fencing and water infrastructure to manage grazing of fragile land types, riparian fencing to reduce degradation of streambank areas and remediation of gullies. As a result of APLMs, 124 GRASS program participation acknowledgement letters were sent to graziers. From July 2020 to June 2021, 124 one-on-one activities and six workshops were conducted. From these activities, DAF staff had interactions with 180 producers from 128 businesses who run 77 322 head of cattle over 498 597 ha of land. Furthermore, 22 properties with a total APLM area of 149 575 ha have had their incentive-funded projects funded.

Exceeding APLM target numbers is consistent with successful delivery by DAF extension staff in other reported QRWQP projects, such as the Grazing Best Management Practices program, where delivery targets were exceeded by 59–96% (Brown 2016). Completion of 138 APLMs resulted in participating producers being considered compliant with the Reef Protection Regulations. Furthermore, the large-scale industry engagement DAF has delivered, has not only increased awareness of the regulations, but the land management practices detailed in the APLMs will lead to more sustainable grazing practices. Landholders that received GRASS program participation acknowledgement letters report that such documentation had been used for a range of purposes including support for applications to financial lenders (D. Connor, pers. comm., 2020). It is recommended that the GRASS program continues delivery in the Great Barrier Reef river catchments of Queensland.

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Online communication channels can influence adoption: a FutureBeef case study

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FutureBeef is a collaboration between Queensland, Northern Territory and Western Australian agricultural departments and Meat & Livestock Australia. It provides a coordinated approach to the delivery of online information and industry engagement for the northern beef industry. FutureBeef utilises a variety of online communication tools, including website, webinars, social media (Facebook, Twitter and LinkedIn), eBulletins and multimedia. The objective of this study was to assess the effectiveness of FutureBeef's online communication channels in influencing adoption of recommended best management practices by northern beef producers.

An evaluation of adoption of best management practices resulting from producers and service providers engagement with FutureBeef's online communication channels was undertaken between March and June 2021. An online survey was emailed to all FutureBeef users (5826 recipients), included in the FutureBeef eBulletin (5812 subscribers) as well as promoted through FutureBeef's social media channels (total of 16 333 followers across Facebook, Twitter and LinkedIn).

The survey was completed by 202 FutureBeef users. Almost half of all survey respondents (48%) indicated that FutureBeef had contributed to the adoption of cattle management practices such as pasture management, supplementation including phosphorus, weaner management, early weaning, feed budgeting and adjusting property stocking rates (Table 1). A further 26% indicated that FutureBeef had contributed to their intention to adopt practices such as pastures and grazing management (pasture improvement, livestock movements and fencing), animal production (cattle and herd management practices) and animal health and welfare (pain relief, vaccinations, and biosecurity). Twenty-five percent of survey respondents reported that the three FutureBeef communication channels, website, webinars and eBulletins, had the most influence on adoption. A further 24% indicated that the same three channels had the most influence on their intention to adopt. Survey respondents were asked to rate the impact to their farm business by the adoption of best management practices promoted by FutureBeef, on a scale from (1) small to 10 (very large). Where some attribution to FutureBeef was reported, there was an average rating of 6.4 out of 10 (6.5 for producers and 5.9 for service providers). The average percentage of the impact of adoption attributed to FutureBeef was 58% for those who had implemented a practice change versus 37% for those who nominated a practice change they intend to implement.

Table 1. Number and percentage of survey respondents that indicated that FutureBeef has supported adoption

Type of respondent	Contribution of FutureBeef to adoption		
	Yes	Intend to in the future	No
All respondents	89 (48%)	48 (26%)	49 (26%)
Producers	65 (49%)	34 (26%)	33 (25%)
Service providers	24 (44%)	14 (26%)	16 (30%)

The survey data indicated that the information provided through FutureBeef's online communication channels was used to support adoption of best management practices by northern beef producers and service providers. This is consistent with Coutts (2016) who conducted a previous survey for FutureBeef, where 68% of respondents indicated that FutureBeef had (37%) or might have (31%) stimulated or supported practice change. Of interest, adoption and intention to adopt was very similar (in percentage terms) between both producers and service providers. This indicated that as well as influencing producers directly, FutureBeef provided resources that enabled service providers to work with clients to stimulate practice change. Three key FutureBeef communication channels that supported adoption were the website, webinars and eBulletins. In contrast, the social media channels (and the eBulletin to some extent) simply 'alerted' people to this information.

In conclusion, this study highlights the effectiveness of FutureBeef's online communication channels in influencing on-farm adoption of best management practices for the northern beef industry.

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Novel annual pasture legumes increase profit and reduce risk in mixed farming

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Annual legume pasture phases have historically been an integral part of mixed farming in southern Australia. However, the level of integration of these phases in modern farming businesses is limited, and new approaches are required so that legume-based pastures remain economically competitive with continuous cropping. There are many potential benefits of mixed crop and pasture systems including reduced inputs, increased profit, improved sustainability, and lower risk. Recently, work undertaken to develop the next generation of annual pasture legumes in farming systems has increased the flexibility and performance of pasture phases (Nutt *et al.* 2021). In this study we used the Land Use Simulation Optimiser model (LUSO; Lawes and Renton 2010) to evaluate profitability and risk of rotations where systems including novel pasture legume systems were compared with cropping dominant systems.

Economic analyses of crop and pasture phases requires a complex understanding of the drivers of value and biological effects generated from their production. To provide input data for the LUSO model, simulation modelling of crop and pasture production was conducted for one location, Corrigin, WA, using Australian farming systems models APSIM and GrassGro. Simulations were run across 30 years (1991–2020) to ensure inter and intra-seasonal variability was considered. LUSO model simulations were then conducted to evaluate the economic return of a particular crop and pasture sequence over six seasons. The LUSO model represents how each crop or pasture within a simulated sequence affects disease population dynamics, weed population dynamics and N, and predicts the effect of each crop on future yields, profits and biotic stresses. Three cropping phases, wheat (W), canola (C), and lupins (L), and four pasture phases volunteer (Pv), improved (Pi), novel (Pn) and ungrazed novel (Pnug) were used in rotations (novel pastures have higher nutritive value and production than improved). Each six-year rotation was run 1000 times, using randomly selected annual weather combinations for each of the phases, with an economic assessment based on five-year average costs and prices.

Phases of improved and novel pastures that were grazed were found to be more profitable than continuous cropping phases (Table 1). The most profitable rotation including pastures (PnWPnCWW) was $117/ha/year higher than the most profitable crop-only rotation (CWWCWW). The profitability of rotations with unimproved pastures was similar to continuous cropping rotations, except for continuous wheat which was less profitable. Under high biotic stress, and average prices, the most profitable continuous cropping rotation over 6 years (CWWCWW) was unprofitable in the poorest 20% of season sequences whereas the profitability of the rotations with novel pasture were more consistent, and higher, than continuous cropping in the least profitable 20% of sequences.

Table 1. Profit ($/ha) of eight simulated rotation sequences of 6 years, with combinations of Wheat (W), Canola (C), Lupins (L), and Volunteer (Pv), Improved (Pi), Novel (Pn) and ungrazed Novel (Pnug) pasture phases

Rotation	1	2	3	4	5	6	Average
CWWCWW	71	146	112	56	107	82	96
LCWPvCW	47	87	133	119	64	109	93
PiWPiCWW	277	195	246	106	120	93	173
PnugWPnCWW	-215	212	341	136	120	93	114
PnWPnCWW	382	212	341	134	120	92	213
PvCWPvCW	142	76	136	122	66	111	109
WWWWWW	136	108	88	65	43	15	76
PnugWWCWW	-215	213	111	55	110	84	60

Our study found that productive legume-based pastures are a profitable option in mixed farming rotations. These pastures have a dual role in supporting a self-replacing Merino enterprise and by reducing biotic stress and nitrogen input costs for subsequent cropping phases. Further, profits were maintained in the least profitable seasonal conditions, compared with cropping-only phases. However, in this study we assumed that the establishment of productive high-quality pastures is always successful, producing high quality livestock feed and fixed N during each pasture phase including the establishment year. If pastures are ungrazed in the establishment year, or all years, there is a large reduction in profit. This research supports the potential for a greater role for novel annual pasture legumes combined with sheep in low-medium rainfall agricultural regions.

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Beef processors experience large variation in yield and quality traits on a daily basis

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Increasingly beef processors are able to extract more value from higher quality carcasses which will increase demand for quality and be reflected in price. Pitchford *et al.* (2020) examined various pricing strategies based on yield and quality and concluded that the majority of variation was associated with yield even when high permiums were placed on quality. However, concerns were raised by processors that the data set used had less variation in quality than they commonly experienced. Thus, the focus of this paper is quantifying variation. There is very little published research on variation in carcass traits at a processor level nor how a single day's variation is representative of that across days. Therefore, the objective of this work was to determine the variation in the yield and eating quality traits over time and between processing plants.

This work was conducted using a subset of the Meat Standards Australia (MSA) database, covering a period of 4 years from the start of 2010 to the end of 2013, totalling 1159 days. This subset covers a range of different lots from all over Australia, processed at nine different plants, covering a total of approximately 1.7 million carcases, covering 35 variables. The carcase weight and traits associated with yield and eating quality variables utilised for this section of work were Hot Standard Carcase Weight (HSCW; kg), Eye Muscle Area (EMA; cm^2), Ossification Score (OSS; score out of 590), MSA Marbling Score (MARB; score out of 1190), MSA Index Score (MSA; percent), P8 fat depth (P8, mm), and Rib fat depth (RIB; mm). The data set was too large for fitting a mixed model to partition the variance. Thus, means were calculated at the plant, year, month, day and lot level to enable calculation of variances at each level. Variance was then partitioned by differences and presented graphically (Fig. 1). Plant differences were not the primary focus of this study and likely reflect differences in markets. The total variance for each trait was HSCW 2506 kg^2, EMA 101 cm^4, OSS 3416 $scores^2$, MARB 8945 $scores^2$, MSA 11.1 $percent^2$, P8 18.3 mm^2 and RIB 12.7 mm^2. Between Plants, Years and Months only accounted for a total of approximately 20% of the variance in most traits. Variation between days was also modest at 9–21%. Thus, the bulk of the variation was between and within lots so processors experience the bulk of the variation in carcass quality on a daily basis.

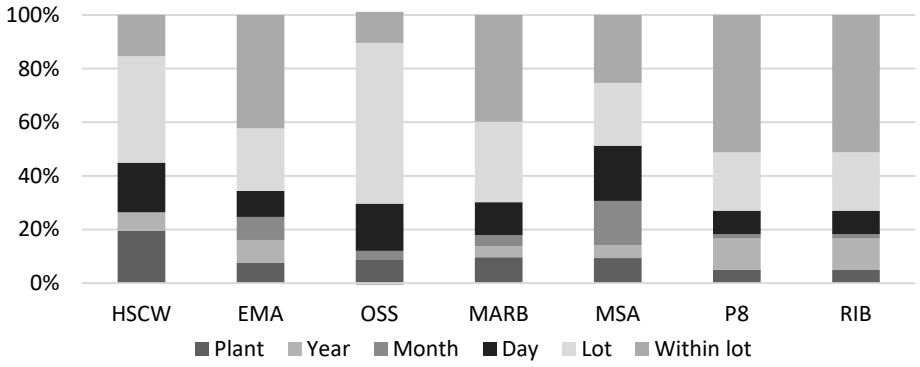

Fig. 1. Sources of variation (as a percentage) for each carcase trait due to processor and time effects (colours in legend bottom).

Pitchford *et al.* (2020) reported results from a bone out trial with animals from a genetics trial that were born and raised together. Thus, there was minimal variation in age and all animals had been managed the same. The animals herein had similar carcass weight, eye muscle area and fat depth to Pitchford *et al.* (2020) but, as expected, the variation in quality experienced by processors was much greater. Processors have large variation in ossification whereas in the bone out trial it was assumed there was none as the animals were not MSA graded. Processors also have much greater variation in marbling so that on a daily basis the standard deviation was 77 relative to 39 scores. The combination of ossification and marbling meant that the standard deviation in MSA index experienced by processors was 2.3 compared with only 0.8 in the bone out trial. Thus, even though it was not measured directly in the MSA dataset herein, it appears that while the bone out trial had representative variation in yield, the variation in quality was far smaller than commonly experienced. The implication of this is that the conclusion about the relative importance of yield and quality should rightly be questioned and will be the subject of further work.

Reference

Pitchford WS *et al.* (2020) Yield measurement is valuable for pricing beef carcasses. *Animal Production Science* **61**(3), 287–293.

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