
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Preliminary investigations into the trait of residual energy intake in sheep

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Abstract

Residual energy intake (REI), also referred to as residual feed intake, is one way of describing feed efficiency, and is an estimate of whether or not an animal is eating more or less than expected for its weight and growth rate. The REI trait has been investigated in a number of production-animal species, but only pilot study data exists for New Zealand sheep. This paper investigates phenotypic variability in the trait of REI for a cohort of 197 growing ewe lambs. The animals were approximately nine months old at the commencement of the trial. Their daily intake of a lucerne pellet-diet was measured for 56 days using an automated feeder that recorded weight of feed consumed in real time. The animals were weighed twice weekly. The standard REI model involves fitting metabolic mid-test live weight and live weight gain to predict energy intake. Both measurements fitted were significant ($P<0.001$), with an overall R2 for the model of 0.78. Grouping of the animals in to Low-, Mid- and High-efficiency groups revealed a 24% difference in energy intake between the low and high groups which is consistent with studies in other species. The comparison of attributes of the efficiency groups did reveal differences in fatness with the high-efficiency animals fatter at the start of the data collection, but they did not lay down as much fat during the trial as the low-efficiency group. Given the phenotypic variability is consistent with that observed in other production-animal species, additional cohorts will be measured in the coming years to generate a data set to investigate the genetics of the trait, and further investigate the role of fat within the REI model.

Keywords: Residual energy intake; sheep

Introduction

In all production systems there is a cost associated with the feed or energy that animals consume. All other things being equal, an efficient animal which requires less energy for its productive outcomes (maintenance, growth, milk production) presents the opportunity to maximise production from a set amount of energy. A trait that describes this type of efficiency is Residual Feed Intake (RFI) as first described by Koch et al. (1963), which can alternatively be expressed as Residual Energy Intake (REI). Based on a meta-analysis of cattle data, from 39 published papers, this trait has been shown to be under genetic control (heritability of 0.33 ± 0.01), and is now included in genetic selection programmes (Berry & Crowley 2013).

Less is known about REI in sheep (Fogarty et al. 2006; Cockrum et al. 2013; Redden et al. 2013), with the only study to investigate REI in New Zealand sheep to date based on a pilot study (Johnson et al. 2015). There is, however, sufficient evidence from these papers to suggest that similar levels of variation to that observed in cattle studies (Williams et al. 2011) do exist in sheep. To investigate variation in REI in New Zealand sheep further, and ultimately estimate genetics parameters for the trait, a multi-year study has commenced with the establishment of a New Zealand sheep REI facility utilising custom-made automated feeders (Johnson et al. 2015). The first cohort of this study, a group of 197 animals derived from New Zealand industry progeny tests were measured in the facility at approximately nine months of age.

A requirement in generating REI data is the need for energy intake data on each animal, along with an accurate description of its weight and growth during the time when energy intake is measured. This paper investigates phenotypic variability for the REI trait for the first cohort of animals which will inform proceeding with the remaining cohorts.

Materials and methods

Permission for this trial was granted from the AgResearch Invermay Ethics Committee (Ethics Number 13563).

The REI facility consisted of five pens of equal size across a raised-floor shed. Each pen could house 40 animals. Within each pen animals had un-restricted access to four automated feed intake machines. The feeders were designed by AgResearch and utilized a feed trough on load cells with automated feed delivery via an auger. Approximately 2.5 kg of feed was always available, allowing *ad libitum* access to feed, with the weight of feed consumed recorded in real time against that animal through the use of electronic identification. The lambs were introduced to lucerne pellets (sourced from JT Johnson & Sons Ltd, Kapunda, South Australia, Australia; dry matter content 88%; metabolisable energy content 10.4 MJ ME; crude protein 21%) over a two-week period before the trial with lucerne pellets available *ad libitum*.

Animals

Two-hundred nine-month-old ewe lambs were sourced from two industry progeny tests; the Central Progeny Test which represents a variety of maternal breeds as described by McLean et al. (2006) and the Woodlands Progeny Test, which historically had a genetic base of Coopworths but has now expanded to include ewes sired by industry sires of different breeds (John McEwan pers comm.). Data was successfully collected on 197 of the animals. The lambs were the progeny of 24 different sires, with each sire represented by eight progeny in the trial with the exception of one sire, the link sire, with 16 progeny, eight from each of the progeny tests. The lambs were randomly assigned, but balanced for sire to be represented in each of five pens within the facility.

Measurements

The lambs were scanned by ultrasound prior to the start of the trial for the size of the *M. longissimus* muscle and the fat depth over this muscle (C). The lambs were CT-scanned at the end of the trial using a spiral CT scanner. Full analysis of the CT data will be published later, but for the purposes of this study, the equivalent image to that generated from the ultrasound was analysed.

The data generated from the automated feeders was summed across a day for an animal to provide the total feed consumed, but the number of feeding events and the average weight of feed consumed at each feeding event was also recorded.

The animals were given two weeks to adjust to the feed and the facility, prior to the start of the planned recording period. The animals were then fed for 42 days, and were weighed twice weekly, at approximately 9 a.m. The importance of using multiple measures of live weight during the trial to accurately estimate average daily live weight gain (ADG) was demonstrated by Johnson et al. (2015).

Analysis

The amount of feed eaten per day by each animal was converted to energy intake by multiplying the amount of feed by the dry matter content, and energy content of the dry matter.

A model based on that of Koch et al. (1963) was used to calculate REI using the GLM procedure in SAS: $y = \beta_0 + \beta_{1*}MMWT + \beta_{2*}ADG + Trial + Pen + \varepsilon$; where y is measured energy intake calculated using the MIXED procedure in SAS, fitting day as a repeated measure, β_0 = intercept, MMWT = metabolic mid-weight (mid-weight$^{0.75}$), ADG = the slope of model estimated by REG procedure in SAS (SAS Inst. Inc., Cary, NC) using the bi-weekly liveweight measurements and the day of measurement (with the first measurement made on day 0), Trial=FlockA or FlockB; Pen=A-E and ε = the residual which is taken as the trait of REI.

The animals were ranked based on their resulting REI values and the bottom and top 15% (n=30) assigned as being Low or High REI respectively, with the remainder assigned as Medium. The significance of differences among the groups was assessed using the GLM procedure in SAS fitting REI group as a fixed effect.

Results

The live weights recorded on an animal, and the derived growth rate of the animal during the trial period are important predictors within the REI model. The goodness of fit of a regression model across the live weights collected for each animal is summarised in Fig. 1. The average starting live weight of the animals was 45.0 ± 6.02 kg with a range of 30.3 to 68.8 kg. The average growth rate during the measurement period was 324 ± 53 g/day with a range of 192 to 476 g/day.

The REI model fitted to determine the relationship between the weight and growth rate of the animals, and their intake had an R^2 of 0.78, with MMWT and ADG significant ($P<0.001$), and Pen not significant ($P=0.46$). The observed standard deviation of the REI trait was 1.2 MJ/day, which was 6% of the average daily intake of the animals.

The results from the grouping of the animals into Low-, Medium- and High-REI groups are in Table 1. Live weights and growth rates were not different between the

Figure 1 Goodness of fit of model fitted to live weight data collected twice-weekly for six weeks

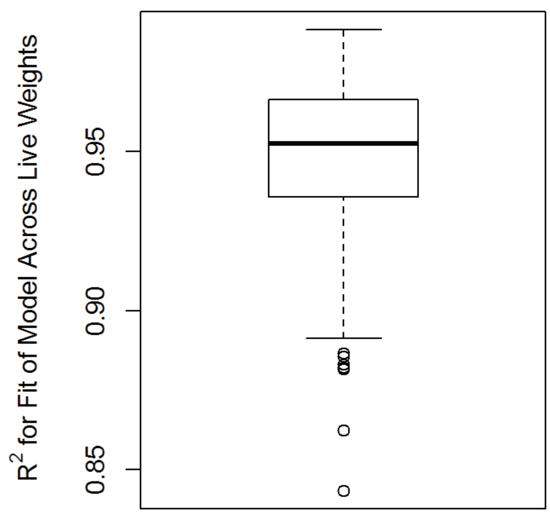

Table 1 Characteristics (average ± SEM) among residual energy intake (REI) group traits

	REI Group			Sig. of
	Low (n=30)	Medium (n=137)	High (n=30)	REI Group
Trial Mid Weight (kg)	49.8 + 1.15	49.6 + 0.53	51.2 + 1.17	NS
Average Daily Gain (g/day)	332 + 9.7	321 + 4.5	327 + 9.9	NS
Energy Intake/Day (MJME)	17.8 + 0.48[a]	19.9 + 0.21[b]	22.5 + 0.55[c]	P<0.001
Residual Energy Intake (MJME/day)	-1.8 + 0.13[a]	-0.0 + 0.05[b]	2.0 + 0.14[c]	P<0.001
Fat depth C – Start (mm)	4.2 ± 0.25[a]	3.9 ± 0.12[a]	3.2 ± 0.25[b]	P<0.05
Fat depth C – End (mm)	4.0 ± 0.32	4.0 ± 0.32	3.7 ± 0.32	NS
Change in fat depth C (mm)	-0.2 ± 0.24[a]	0.1 ± 0.1ab	0.5 ± 0.24[b]	P=0.09

[1]Values within a row with different superscripts are significantly different (P<0.05)

REI groups as expected given they were fitted in the model to derive REI. Both REI and daily energy intake were significantly different between the REI groups, with the most efficient animals (Low REI) consuming on average 4.2 MJ/day less energy, or 24% less than the least-efficient animals (High REI). There were significant differences in C measured at the start of the trial, with the most-efficient animals being fatter. Although not significant, there were suggestive ($P<0.10$) differences in changes in fatness during the course of the trial, with the least efficient animals laying down more fat as measured by change in C between the end and start of the feeding period.

Discussion

The cohort of growing lambs used in this study are the first of several planned cohorts in a multi-year study that aims to collect data on over 1000 growing lambs representing 125 sires to enable the estimation of the heritability of the trait of REI and genetic relationships between REI and other production traits. However, before further data collection could be justified, the data from first cohort needed to be analysed to ensure that the trait of REI could be calculated, and showed similar levels of variation to that observed in other sheep and cattle studies.

As reported by Johnson et al. (2015) the ability to obtain accurate live weight gain profiles is difficult, but can be achieved through regular weighing of the animals during the period of measurement. The accuracy with which the live weight gain could be described in these animals was comparable to that reported by Johnson et al. (2015) and Williams et al. (2011). The R^2 of the REI model generated in this study (0.78) was comparable to that of Johnson et al. (2015), but is higher than the range of 0.45 to 0.65 reported by Redden et al. (2013) and Cockrum et al. (2013) in sheep using the same model of Koch et al. (1963). The observed phenotypic standard deviation of REI relative to overall intake, of 6%, is comparable to the results observed by Johnson et al. (2015) and those summarised for beef and dairy cattle by Williams et al. (2011).

The results from assigning the animals to Low-, Medium- and High-REI groups demonstrated that the live weights and growth rates were not significantly different between the REI groups as expected given they were fitted in the model used to derive REI. Both REI and energy intake were significantly different between the REI groups. The size of the difference in REI between the Low- and High-REI groups are consistent with the reports of differences of 17 to 30% in sheep and cattle (Williams et al. 2011; Cockrum et al. 2013; Redden et al. 2013; Johnson et al. 2015). Of interest are differences in fatness among the different REI groups. In sheep studies to date, similar differences have not been observed. Cockrum et al. (2013) only made one measure of fatness at the end of their trial. Although Redden et al. (2013) similarly measured fat depth at the start and end of the trial and change in fatness, they did not find any significant differences among REI groups. It is reasonable to hypothesise that potential differences in efficiency could occur because of differences in fatness. As reviewed specifically for ruminants by Ball et al. (1997), there are differences in the energy requirements of muscle and adipose tissue for accretion and subsequently, maintenance. Specifically, the energy cost of muscle accretion is lower than for adipose, but that conversely the energy cost of maintaining a unit weight of protein is higher than that for adipose. Thus, in this study there may be confounding effects, in that the animals that were described as efficient had increased fat at the outset, and deposited less fat during the time of the trial. In some studies, measures of fatness are added to the model of Koch et al. (1963) (Basarab et al. 2011), and the review by Berry and Crowley (2013) suggested that it should be included. Future analysis of the data will, therefore, need to investigate the inclusion of fatness measures in the base model, but it has been useful to present the results in the current format, as the relationship to fatness has not previously been observed (as discussed above).

A single full-spiral computed tomography (CT) image was collected on the animals at the conclusion of the study. As discussed by Johnson et al. (2016), there is significant variation in the location of adipose deposition among animals, and as such, the fat depth measures over the *M. longissimus* may not fully represent the total fat of the animal, and the CT data does present an opportunity to account for this more accurately.

The multi-year study that this cohort is part of has been optimally structured to generate data from which genetic parameter estimates for REI can be obtained. This optimisation recommended that only eight progeny per sire were measured, and as such, the ability to investigate among-sire differences is limited in this current data set.

Conclusion

Residual Energy Intake is a measure of whether or not animals are eating more or less than expected given their live weight and growth rate. This paper has demonstrated that variation in REI does exist in New Zealand growing lambs, with the level of variation consistent with reports from overseas sheep and cattle studies. Inconsistent with the literature is a potential relationship between levels of body fat and REI which will need to be investigated further. Overall, these results support the collection of further REI data to ultimately investigate the genetic control of the trait of REI in New Zealand sheep.

Acknowledgements

This was a Beef + Lamb New Zealand Genetics project funded by the Ministry for Business, Innovation and Employment and Beef + Lamb Zealand. The animals sourced from the Woodlands Progeny Test were funded by New Zealand Agricultural Greenhouse Gas Research Centre and Pastoral Greenhouse Gas Research Consortia, who are partners in this project for extended measurements not reported herein. AgResearch capital expenditure funding supported the production of the automated feeders.

References

Ball AJ, VH Oddy and JM Thompson 1997. Nutritional manipulation of body composition and efficiency in ruminants. Recent Advances in Animal Nutrition in Australia. Armidale, Australia, University of New England, Armidale.

Basarab JA, MG Colazo, DJ Ambrose, S Novak, D McCartney and VS Baron 2011. Residual feed intake adjusted for backfat thickness and feeding frequency is independent of fertility in beef heifers. Canadian Journal of Animal Science 91: 573-584.

Berry DP and JJ Crowley 2013. Cell biology symposium: Genetics of feed efficiency in dairy and beef cattle. Journal of Animal Science 91: 1594-1613.

Cockrum RR, RH Stobart, SL Lake and KM Cammack 2013. Phenotypic variation in residual feed intake and performance traits in rams. Small Ruminant Research 113: 313-322.

Cockrum RR, RH Stobart, SL Lake and KM Cammack 2013. Phenotypic variation in residual feed intake and performance traits in rams. Small Ruminant Research 113: 313-322.

Fogarty NM, GJ Lee, VM Ingham, GM Gaunt and LJ Cummins 2006. Variation in feed intake of grazing crossbred ewes and genetic correlations with produciton traits. Australian Journal of Agricultural Research 57: 1037-1044.

Johnson PL, WE Bain, P Johnstone, MJ Bixley and K Knowler 2016. Variation in total body adipose and adipose partitioning in maternal sheep estimated using computed tomography scanning. Proceedings of the New Zealand Society of Animal Production 76.

Johnson PL, SP Miller and K Knowler 2015. Towards a data set to investigate feed efficiency in new zealand maternal sheep. Proceedings of the Association for the Advancement of Animal Breeding and Genetics 21: 106-109.

Johnson PL, SP Miller, K Knowler, B Bryson and KG Dodds 2015. Brief communication: Modelling liveweight change to inform a residual feed intake model in sheep. Proceedings of the New Zealand Society of Animal Production 75: 225-227.

Koch RM, LA Siger, D Chambers and KE Gregory 1963. Efficiency of feed use in beef cattle. Journal of Animal Science 22: 486-494.

McLean NJ, NB Jopson, AW Campbell, K Knowler, M Behrent, G Cruickshank, CM Logan, PD Muir, T Wilson and JC McEwan 2006. An evaluation of sheep meat genetics in new zealand: The central progeny test (cpt) Proceedings of the New Zealand Society of Animal Production 66: 368-372.

Redden RR, LMM Surber, AV Grove and RW Kott 2013. Growth efficiency of ewe lambs classified into residual feed intake groups and pen fed a restricted amount of feed. Small Ruminant Research 114: 214-219.

Williams YJ, JE Pryce, C Grainger, WJ Wales, N Linden, M Porker and BJ Hayes 2011. Variation in residual feed intake in holstein-friesian dairy heifers in southern australia. Journal of Dairy Science 94: 4715-4725.