SOME CONSEQUENCES OF SELECTION FOR RESIDUAL FEED INTAKE IN BEEF CATTLE

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SUMMARY

Body composition and energy expenditure were investigated in Angus heifers divergently selected for residual feed intake. Differences in fat deposition at rib and rump sites were observed between the lines but there was no difference in protein deposition, weight gain or energy expenditure. Most of the variation in energy expenditure could be accounted for by the metabolisable energy consumed by the animal. The implications of this observation on the biological consequences of selection for residual feed intake are discussed. These are preliminary observations and further work on the biological basis of the trait is required to provide definitive answers.

INTRODUCTION

In typical beef production systems, the cost of feed accounts for over half of the total cost of production. Accordingly, improvements in the efficiency of feed utilisation are a desired management objective. There is phenotypic variation in feed intake independent of variation in average weight and weight gain (termed residual feed intake, RFI) and is moderately heritable (Arthur *et al.* 2001a; Arthur and Herd 2008). Selection of beef cattle for and against RFI measured shortly after weaning has been underway for almost a decade (Arthur *et al.* 2001a; Arthur and Herd 2008). Here we used animals divergently selected for RFI for 3-4 generations to investigate possible biological mechanisms contributing to the trait.

In beef cattle divergently selected for RFI for 1 generation, up to 95% of the variation in RFI was attributed to differences in energy expenditure (as heat production) rather than to energy retained in body tissues (Richardson and Herd 2004). These authors suggested energy expenditure associated with whole body protein turnover, tissue metabolism and stress could contribute 37% of the variation in RFI. The energy costs of protein turnover contribute 20-25% of maintenance energy expenditure and 15-20% of basal metabolic rate across a range of species; protein synthesis alone may contributes up to 30% of heat production in cattle (reviewed by Richardson and Herd 2004). There is particular interest in the effects of selection for reduced RFI on the efficiency of energy use because it was originally hoped that selection would result in reduced maintenance energy and therefore, feed requirements. The aim of this study was to assess the contribution of protein synthesis to energy expenditure in young beef cattle selected for and against RFI. Here we report the data on energy expenditure, and briefly refer to preliminary results of protein synthesis measurements.

MATERIALS AND METHODS

Sixteen (16) Angus heifers from a research population divergently selected for approximately 3-4 generations for high RFI (low "efficiency"; n=8, average mid-point parental RFI EBV=0.64±0.07 kg/d) or low RFI (high "efficiency"; n=8, average mid-point parental RFI EBV=-0.78±0.26 kg/d) were used, where the parental EBV's were calculated by BREEDPLAN. They were fed diets 105% maintenance requirements (MR) and 95% *ad libitum*, equal to approximately 180% MR, in a crossover design. The crossover design was implemented to reduce individual animal differences from the overall treatment effects, hence increasing the statistical power of the experiment resulting in the use of fewer animals. First; one half (4 high RFI and 4 low RFI) were fed at 180% MR and the other half (4 high RFI and 4 low RFI) fed 105% MR. After adaptation to this feeding level for 21 days, the following measurements were taken: Subcutaneous rump and rib fat depth, eye muscle area (EMA) and intramuscular fat content (IMF) were measured using an ultrasound scanner. Energy expenditure was estimated by infusion with 17.5 µmol/kgBM ^{13}C-sodium bicarbonate similar to the method of Li *et al.* (2008) and protein synthesis by continuous infusion with 10 µmol/kgBM$^{0.75}$/hr ^{13}C-leucine and analysed by the method of Calder and Smith (1988). Dietary treatments were switched and the measurements were taken again so that measurement duration was 35 and 42 days for periods 1 and 2. Each animal was measured twice, once at low and high feed intake. The animals were fed twice daily of a diet of 50% grain, 40% chopped sorghum hay, 9% Molofos® and 1% minerals. The diet was estimated to contain 11.5MJ metabolisable energy and 12.5g of crude protein/kg dry matter. Feed refusals were weighed twice daily. Data were analysed with a general linear model including factors for RFI line, diet, time of measurement, animal and all interactions between factors with initial body weight as a covariate. Tests of significance for main effects were based on type I sums of squares. Significance was defined as P<0.05.

RESULTS AND DISCUSSION

No interactions were observed between RFI line and feeding level for the body composition traits. Feeding level had the largest effect on the change in body composition traits during the measurement periods. Heifers fed at 180% MR grew faster and laid down more fat over the rump and ribs, and as IMF than heifers fed 105% maintenance (Table 1). Additionally, the low RFI heifers had lower rump and rib fat deposition (P<0.05), but not IMF deposition, than the high RFI heifers, regardless of feeding treatment.

Table 1. Main effects means and SEM for absolute changes over the treatment periods in weight and tissue depots for high and low RFI heifers fed at either 105% or 180% maintenance feeding levels

Main effects	Treatment	ADG (kg/d)	EMA (cm^2)	Rump fat (mm)	Rib fat (mm)	IMF (%)
RFI line	Low	$0.66^a \pm 0.12$	$4.2^a \pm 0.61$	$1.0^a \pm 0.30$	$1.0^a \pm 0.27$	$0.9^a \pm 0.16$
	High	$0.70^a \pm 0.11$	$4.8^a \pm 1.07$	$1.9^b \pm 0.52$	$1.4^b \pm 0.38$	$0.9^a \pm 0.21$
Feeding level	180% MR	$0.88^a \pm 0.09$	$4.8^a \pm 0.85$	$2.4^a \pm 0.33$	$2.0^a \pm 0.24$	$1.3^a \pm 0.16$
	105% MR	$0.47^b \pm 0.09$	$4.3^a \pm 0.89$	$0.5^b \pm 0.41$	$0.4^b \pm 0.27$	$0.5^b \pm 0.15$

Within main effects, means with different superscripts differ significantly (P<0.05). Interactions between main effects were not significant.

Diet affected energy expenditure (Figure 1) in that animals fed at 105% MR had lower energy expenditure than animals fed at 180% MR, but there was no significant difference between the RFI genotypes. However, most of the variation in energy expenditure or heat production can be accounted for by the energy consumed by the animal. Hence, it suggests that there is no detectable difference in the efficiency of energy utilisation between the RFI lines (Figure 1). Energy expenditure for muscle protein synthesis was highly correlated to whole body energy expenditure (r=0.73). However, there was no difference in muscle protein synthesis between RFI lines and therefore, appears not to contribute to the between RFI line variation in energy expenditure observed in these animals.

Although there is substantial variation around the relationship, if correct, the analyses suggest that selection for RFI has resulted in no detectable change in the efficiency of utilisation of feed energy. However, RFI is heritable and the phenotype of the animals has changed as intended with selection (Arthur *et al.* 2001a; Arthur and Herd 2008). What are the implications if there has been no change in the relationship between energy expenditure and energy intake?

Kennedy *et al.* (1993) and Van der Werf (2004) elegantly demonstrated that selection of a trait such as RFI where FI = Weight + Production parameter + RFI is equivalent to selection on the component traits. So if selection for RFI has resulted in a reduction in feed intake, at constant weight and daily gain (as it has in this case, Arthur *et al.* 2001b) and no change in the relationship between energy intake and expenditure (this study), it follows that the energy content of gain (= fat content) must be less. This is exactly what has been observed in these animals (Table 1) and by Richardson *et al.* (2001) and inferred by the genetic and phenotypic correlations reported by Robinson and Oddy (2004).

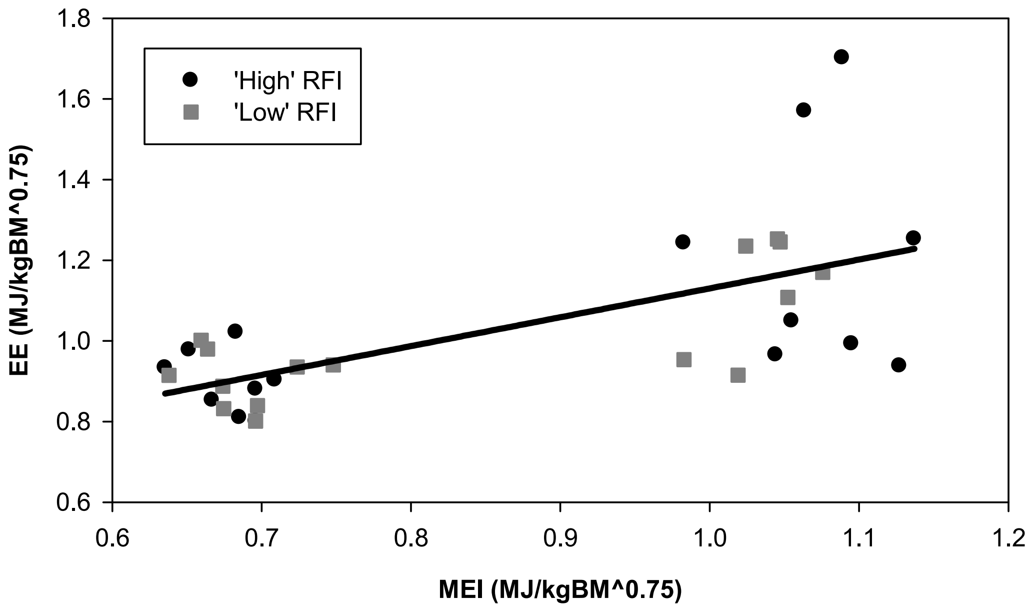

Figure 1: Energy expenditure of high and low RFI heifers against metabolisable energy-intake.

The current study was on a limited number of animals, and the measurements of energy expenditure were by indirect methods. What additional evidence is there that animals which vary in RFI do not vary unexpectedly in energy transactions? Basarab *et al.* (2003) calculated that RFI was related to the composition of liveweight gain and that some of the variation in RFI could be explained by variation in empty body fat gain. When RFI was adjusted for gain in ultrasound back fat thickness and marbling, they showed that animals with negative RFI values had lowered metabolisable energy intakes, lowered heat production (energy expenditure) and retained less energy. They, therefore, concluded that a proportion of the metabolisable energy intakes of high RFI animals was accounted for by the differences in composition of gain. However, a much greater proportion could be attributed to differences in heat production. This relationship between metabolisable energy intake and heat production is exactly what would be expected from nutrition and energetic models.

CONCLUSION

In this study, most of the variation in energy expenditure could be accounted for by the amount of energy consumed. Energy expenditure per unit of metabolisable energy-intake did not differ between the selection lines. There was evidence for differences in fat deposition; the high-RFI animals retained more energy in fat. Modelling energy transactions suggested that there was no difference in efficiency of energy utilisation between the RFI lines. As this study and others show, any perceived differences in efficiency of the trait can be attributed to the amount of energy consumed by the animal and the divergence of fat deposition in the genotypes or phenotypes. However, as small numbers of animals were sampled in this trial, further physiological and biochemical evaluation is necessary before firm conclusions can be drawn.

Given the practical limitations for the measurement of the components of residual feed intake, (that is, actual feed intake, weight and average daily gain), then it is no surprise that selection pressure is extended on feed intake and composition of gain (relative proportion of fat and lean). Unfortunately, basal or underlying metabolic rate, the trait we desire to minimise appears at this stage to be unaltered. These concerns of selection pressure on feed intake and fat deposition associated with selection for residual feed intake should be addressed. Therefore, clearly more work needs to be undertaken to understand the full consequences of selection for RFI and before of the trait can be properly implemented within industry.

ACKNOWLEDGEMENTS

The authors thank the NSW Department of Primary Industries for access to the heifers.

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