SELECTION FOR RESIDUAL FEED INTAKE CAN CHANGE METHANE PRODUCTION BY FEEDLOT STEERS

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SUMMARY
A 70-day residual feed intake (RFI) test on a barley-based feedlot ration was conducted, over which daily feed intake (FI) and weekly liveweight of 91 Angus steers were recorded. Rate of enteric methane production (MPR) was measured in a series of 5 x 2-day consecutive measurement periods using a marker-based method with the marker gas (SF_6) released from an intraruminal permeation device. Data for 76 steers with 3 or more valid 2-day methane collections were analysed. The 43 low-RFI (high efficiency) line steers (progeny of 9 sires) and the 24 high-RFI (low efficiency) line steers (5 sires) represented approximately 2.4 generations of divergent selection for postweaning RFI. An additional nine intermediate unselected line steers were included. MPR (g/day) was highly-significantly related to daily FI (kg/day) over the 10-day gas-collection period: MPR=13.0 ±3.0 (se) x FI +34.9, although FI (P<0.0001) explained only 20% of the variance in MPR. From this relationship MPR over the 10-week RFI test was predicted. MPR predicted for the low-RFI line steers was not significantly lower than for the high-RFI line steers (187 ±4 *v* 199 ±4g/day; P>0.05). Regression analyses showed MPR to be significantly related to genetic variation in RFI (P<0.05), such that a 1 kg/day reduction in estimated breeding value for RFI would be accompanied by a 13.0 ±5.1g/day, or 7%, reduction in methane production. This result supports predictions that reduction in methane emissions should accompany the reduction in FI following from selection for lower RFI.
Keywords: beef cattle, methane, feed efficiency, residual feed intake, greenhouse gas

INTRODUCTION
The agricultural sector is a major source of greenhouse gas emissions worldwide and methane from livestock is a significant component of this. There are currently few practical strategies to reduce enteric methane emissions from livestock without reducing stock numbers (Herd *et al*. 2002). Since methane production is highly dependent on the quantity of feed consumed (Blaxter and Clapperton 1965), reducing feed intake is one way of reducing emissions. Residual (or net) feed intake (RFI) is a measure of feed efficiency in beef cattle and is calculated as the amount of feed consumed net of that predicted based on weight and gain. Cattle with low RFI eat less than expected for their weight and growth rate, and are therefore more efficient than cattle with high RFI. That it is possible to breed cattle that consume less feed than anticipated for their weight and growth rate offers the potential to reduce methane production by selection for lower RFI (Herd *et al*. 2002). This study sought to quantify the association of RFI with methane production by cattle consuming a feedlot diet.

MATERIALS AND METHODS

Cattle breeding and feedlot RFI testing. Cattle breeding and postweaning tests for RFI were conducted at the Agricultural Research Centre, Trangie, NSW, Australia. Establishment of divergent selection lines for low-RFI (high efficiency) and high-RFI (low efficiency) was described by Arthur *et al*. (2001). Male calves born in 2001 were used in this experiment and were the result of approximately 2.4 generations of divergent selection, or were from an intermediate unselected line. Following backgrounding growth on pasture the steers entered the CRC for Cattle & Beef Quality "Tullimba" Research Feedlot (Armidale, NSW) approximately 20 months old and weighing an average 462kg. The steers transited a standard induction program until consuming a finishing ration that consisted of approximately 75% grain, 10% sorghum hay, 5% protein pellets, plus molasses and vitamin and mineral additives (fresh weight basis). Eight feedlot pens, each containing an automated feed-intake recorder (Ruddweigh, Guyra, NSW) and able to accommodate 12 steers, were available. The 96 steers selected for the experiment were chosen on the basis that they covered the full range of estimated breeding values for RFI (EBV_{RFI}) available within the group, and were allocated to the 8 feedlot pens (12 animals/pen) such that the mean weight and EBV_{RFI} of the pens did not differ. After a 3-week pre-test period, individual daily feed intakes (FI) were recorded for a 10-week RFI test. Unfasted liveweights of the steers were recorded weekly.

Methane production rate measurement. Methane production rate (MPR) was measured in two randomly selected pens of cattle per period over 4 consecutive experimental periods. MPR was measured using a marker-based method with the marker gas (SF_6) released from an intraruminal permeation device (Hegarty *et al*. 2003). All steers were fitted with the halter and gas collection apparatus for 5 days prior to measurements being made to enable then to adapt to the equipment. Gas collections were then made over 10 consecutive days, being 5 x 2-day collection periods. The steers were weighed every second day. Every day the steers being measured were walked through the cattle yards and the halter and collection apparatus checked for damage. Methane and SF_6 were measured by infra-red spectrometry and by gas chromatography respectively.

Data analysis. Five animals were removed due to inappetence early in the RFI-test period, leaving 91 steers that completed the test. Feed intakes were calculated as kilograms per day of a ration equivalent to 12MJ metabolizable energy/kg dry matter. Start-of-test, mid-test and end-of-test weights, and average daily gain (ADG) for each steer were calculated from the linear regression of its weekly LW against time. Feed conversion ratio (FCR) was calculated as daily FI/ADG. RFI for each animal was calculated as the residual from the regression of the individual FI by the 91 steers on their mid-test weight$^{0.75}$ and ADG. Gas collections over some 2-day periods for some steers were void because the collection apparatus was damaged. Only results for 76 steers with 3 or more valid 2-day collections were used, and the mean MPR over those periods was calculated for each steer. The MPR measured over the 10-day gas-collection period could not be assumed to apply over the full 10-week RFI test because it was apparent that interference to the steers over the gas collection period caused some animals to have a changed FI compared to outside this period. To facilitate comparison of methane production in relation to RFI over the 10-week test, MPR for the 10-week period was predicted from the MPR:intake relationship established over the 10 days of methane measurement. Over the 10-day period of gas collection MPR (g/day) was correlated with daily FI (FI_{10}; kg/day), such that MPR=13.0 ±3.0 (se) x FI_{10} +34.9, which although statistically highly-significant (P<0.0001) explained only 20% of the variance in MPR.

The data set analysed contained results for 43 low-RFI line steers and 24 high-RFI line steers, plus 9 unselected steers. The low-RFI line steers were the progeny of 9 sires (mean 4.8 progeny per sire: range 2 to 7) and the high-RFI line steers the progeny of 5 sires (mean 4.8 progeny: range 4 to 5). Differences in the means for the low-RFI and high-RFI line steers were tested within a general linear mixed model. Included in the model were the fixed effects of age of dam, feedlot pen and selection line, steer age at feedlot entry as a covariate, and sire within line as a random effect. Selection line differences were tested against the sire-within-line mean squares. Preliminary analyses showed that age-of-dam and age-of-steer were not significant (P>0.05) and were dropped from the final model. The low number of animals meant that this approach lacked the power to detect all but large differences between the selection lines. An alternate approach was used to detect whether there was evidence for a genetic association between traits and postweaning RFI. Regressions were determined between traits measured on the steers against the mid-value of their sire and dam EBV_{RFI}. These EBVs had been previously calculated for each parent based on its performance in postweaning RFI tests conducted at the Trangie Agricultural Research Centre. Regression coefficients were determined within a model that included feedlot pen and mid-parent EBV_{RFI}. Regression coefficients significantly different from zero were presumed to provide evidence for genetic association.

RESULTS AND DISCUSSION

Following approximately 2.4 generations of divergent selection, the steers from the low-RFI line started the 10-week RFI-test at the same liveweight, grew as fast over the test, and finished with comparable final liveweight, as steers from the high-RFI line (Table 1).

Table 1. Mean (±se) growth, feed intake and methane production over a 10-week RFI test by steer progeny following approximately 2.4 generations of divergent selection for low postweaning RFI (high efficiency) or high RFI (low efficiency), and regression coefficients with midparent EBV_{RFI}

	Selection line			Regression on
	High efficiency	Low efficiency	P	parental EBV_{RFI}
Number of steers	43	24		76[+]
Midparent EBV_{RFI} (kg/day)	-0.46 ±0.02	0.62 ±0.03	*	
Initial weight, kg	545 ±7	535 ±10		2.5 ±10.4
Average daily gain, kg/day	1.49 ±0.05	1.48 ±0.06		0.00 ±0.07
Final weight, kg	647 ±8	638 ±11		2.5 ±12.3
Feed intake, kg/day	11.7 ±0.3	12.7 ±0.3		1.00 ±0.40*
Feed conversion ratio, kg/kg	8.11 ±0.23	8.80 ±0.30		0.62 ±0.38[†]
Residual feed intake, kg/day	-0.39 ±0.17	0.64 ±0.19	*	0.95 ±0.26*
Enteric methane production, g/day	187 ±4	199 ±4		13.0 ±5.1*

* denotes significant (P<0.05) selection lines differences, or regression coefficient, [†] P=0.10

[+] includes results for 9 unselected steers.

Daily FI and FCR by the low-RFI line steers were not significantly lower than that by the high-RFI line steers, but the low RFI-line steers did display lower RFI (indicating superior feed efficiency).

The regression coefficients for these traits with midparent EBV_{RFI} confirmed that no change in weight or ADG in the feedlot accompanied genetic variation in postweaning RFI, but that changes in FI, FCR (at P=0.1) and RFI did accompany genetic variation in RFI.

The predicted MPR for the 10-week test was phenotypically related to RFI: MPR=11.7 (±1.9; P<0.0001) x RFI +191, with RFI explaining 33% of the variance in predicted MPR, and indicating that animals expressing lower RFI produced less enteric methane. Methane production predicted for the low-RFI line steers was not lower than that for the high-RFI line steers, but was related to genetic variation in RFI, such that a 1 kg/day reduction in EBV_{RFI} would be accompanied by a 13g/day, or 7%, reduction in predicted methane production (Table 1). This is a greater reduction in MPR per kg decline in intake of this diet than would be predicted by Blaxter and Clapperton (1965), who found MPR relatively insensitive to intake of high energy-density diets consumed at levels 2-to-3 times maintenance. This, together with the large day-to-day variation in FI by the steers, may explain why only a small part of the variation in MPR (20%) was explained by variation in FI intake in this experiment.

The regression results in this experiment showed that selection of cattle on the basis of a lower EBV_{RFI} would be accompanied by favourable reduction in FI, FCR, RFI and methane production by feedlot steers. The effects of divergent selection on MPR were difficult to quantify accurately because of: the different duration of RFI and MPR measurements and the effect of MPR measurement on FI; and because the high intake and digestibility of the diet meant ruminal MPR was likely to have been less sensitive to FI than for a forage diet. The genetic correlation between postweaning RFI and MPR by steers is not known but results from this experiment support the predictions that a reduction in methane should accompany the reduction in feed intake following from selection for lower RFI (Okine *et al*. 2001, Herd *et al*. 2002). Future studies should be directed at quantifying relationships between FI and MPR in grazing animals, which produce >96% of enteric methane arising from Australian livestock (NGGIC 2002), and where MPR should show a closer association with FI than with the feedlot diet used in this experiment.

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