Improving feed efficiency of animals in your herd

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Abstract. This paper presents the evidence for genetic variation in feed efficiency in beef cattle. Net feed intake (NFI) is the measure of feed efficiency adopted by the Australian beef industry for the purpose of genetic improvement. NFI measures how much more or less an animal eats compared to its expected feed requirement for its size and growth rate. By this measure of feed efficiency, more efficient cattle are those that eat less than expected and have a negative NFI; less efficient cattle eat more than expected and have a positive NFI. NFI is moderately heritable (about 0.4; similar to growth rate). Experiments on cattle following divergent selection have confirmed that sires and dams selected for low NFI (high efficiency) have progeny who are more efficient at pasture and in the feedlot, than the progeny from parents selected for high NFI (low efficiency).

Data generated from both research and commercial industry testing for NFI formed the basis of a Trial Breedplan estimated breeding value (EBV) for NFI that has been available since early 2002. In 2004, the concentration of Insulin-like Growth Factor-I in blood was used to increase the number of Angus cattle with NFI EBV. Breeding for improved feed efficiency, using cattle with lower NFI EBV, can be expected to produce steer and heifer progeny that require less feed at pasture or in the feedlot, with no compromise in growth, carcase or reproductive performance. Significant savings in feed costs can be expected as more bulls that are genetically superior for NFI are bred by the seedstock

Introduction

To remain profitable the beef industry needs to keep costs low. The cost of providing feed to cattle is the single largest recurring cost of beef production. In the pig and poultry industries, where cost of feed is easily quantified, there has been significant improvement in feed efficiency through both genetic and non-genetic means. Although the cost of providing feed to grazing animals is more difficult to quantify in extensive grazing industries, the provision of feed is a major cost in beef production, and improvement in feed efficiency of animals would be of significant economic benefit.

Genetic improvement in feed efficiency is only one of the tools available to beef producers. It has the advantage over non-genetic methods of being cumulative and is maintained without on-going input costs following the purchase of superior bulls. In the absence of any deleterious genotype-by-environment interaction, genetic improvement can be additive to improvement made through management.

This paper reviews our knowledge about genetic variation in feed efficiency in beef cattle, and presents the most recent Australian research, that together show selective breeding of cattle can be used to reduce the feed costs of beef production, from pasture and in the feedlot.

Management (or non-genetic) improvement

For producers feeding young cattle the factors affecting profitability include: market price, feed cost and feed conversion efficiency of the cattle, usually measured as feed conversion ratio (FCR; feed eaten:weight gained).

Management practices that increase the amount of feed energy consumed by growing cattle usually increase the rate of liveweight gain and improve FCR. Providing cattle with more pasture of higher digestibility, increasing the proportion of grain in a diet, and processing that grain are common non-genetic methods used to get more feed energy into cattle. Utilising cattle that have a propensity for faster growth will also generally improve FCR. Examples of these cattle include cattle undergoing compensatory gain and cattle implanted with a growth promotant. Management practices that shelter cattle from stress, disease, parasites and environmental extremes will also influence FCR.

Genetic improvement

Genetic improvement in the past has concentrated on increasing production, with little effort directed at reducing the feed cost of production, due mainly to the difficulty in measuring feed intake of cattle.

Selection for growth rate has been extensively practised. Growth rate is moderately heritable (about 0.4), is easy to measure and the result of selection: bigger animals, is easy to see. Selecting for faster growing cattle will improve FCR of feedlot cattle, but will also increase animal size and their expected feed requirements. Although the steer component of each year's calf drop is destined for slaughter, the majority of their heifer siblings end up in the breeding herd as replacements. Therefore, an increase in cow size and feed intake may not always be desirable.

Genetic improvement can be achieved through choice of breed, crossbreeding, importation of semen or embryos from "superior" cattle, or by within-breed selection based on estimated breeding values (EBV). This paper will focus on selection within a breed to improve the feed efficiency of cattle. For this purpose, an EBV for feed efficiency is required, along with knowledge of the genetic associations with other important production traits.

Feed conversion ratio

There have been attempts at genetic improvement in feed utilisation based on selection to lower FCR. The results indicate that selection for lower FCR is similar to selecting for increased growth rate, because of the strong genetic association between FCR and growth. Moreover, selection for FCR may result in bigger cows, which may not be desirable (Herd and Bishop 2000).

What is net feed intake?

Net feed intake (NFI)

Net feed intake (NFI) is the measure of feed efficiency adopted by the Australian beef industry for the purpose of genetic improvement. NFI measures how much more or less an animal eats compared to its expected feed requirement for its size and growth rate. By this measure of feed efficiency, more efficient cattle are those that eat less than expected and have a negative NFI; less efficient cattle eat more than expected and have a positive NFI. NFI is sometimes also called residual feed intake.

Evidence for genetic variation in NFI has been reported in a range of beef cattle breeds in studies from Australia, the USA, Britain, Canada, and France. NFI is moderately heritable (about 0.4; similar to growth rate). Selection for low NFI (high efficiency) has produced progeny who are more efficient at pasture and in the feedlot, than the progeny from parents selected for high NFI (low efficiency). The research evidence supporting these conclusions was recently reviewed by Herd *et al.* (2002).

NFI has the important benefit of being independent of the animal's weight and weight gain. It allows a fair comparison of big, medium and small cattle, and selection using NFI need not result in an increase in mature size.

How is NFI measured?

Feed intake tests can be conducted either on-farm or, more commonly, at central test stations. Individual feed intakes are currently measured over a test period of 70 days. While manual feeding systems can be used, most results have been obtained from feeding systems where cattle with electronic identification feed from automated self-feeders.

The most commonly tested stock are young bulls, but some data from steer and heifers is also used. Test cattle are offered more than they can eat of a medium-energy hay and grain ration, they are weighed regularly, and their feed intake compared with their growth performance in order to determine if they have eaten more or less than expected. Test protocols are set out in an accreditation manual (NSW Agriculture 2001), and only data from accredited tests are accepted by Breedplan. This is on the recommendation of the Performance Beef Breeders Association, the body representing Australian breed societies in Group Breedplan.

NFI EBVs

Data generated from both research and commercial industry testing for NFI formed the basis of a Trial Breedplan EBV for NFI that has been available since early 2002. To date, 3 breeds, Angus, Hereford and Poll Hereford, have sufficient well-linked data, to have

Table 1. Understanding NFI EBV.

Two bulls have the following NFI EBVs. The breed average is, say, 0.

Bull A: +0.5 kg/day

Bull B: –0.7 kg/day

A simple interpretation is that bull B, having a more negative NFI EBV, would be expected to breed 'more efficient' progeny than bull A or a breed average bull. If the 2 bulls were similar in their weight EBVs, and both were joined to 'average' cows, the progeny of bull B would eat 0.6 kg less per day than the progeny of bull A (0.6 kg is half the 1.2 kg difference between the sire NFI EBVs, as the cows also contribute half the genes; also assumes yearling progeny are on a similar diet to their parents test ration).

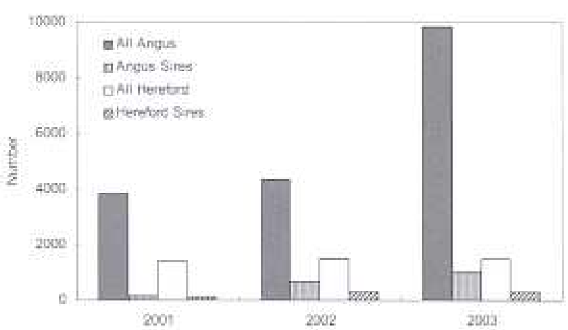
their data analysed to calculate across-herd EBVs. Several high and low efficiency bulls in each breed have been identified. NFI EBVs are reported as kilograms of feed eaten per day (of 10 MJ ME/kg DM ration). Like most EBVs, the NFI EBV can be positive (+) or negative (–) relative to the breed average. The more negative the NFI EBV, the less feed eaten and the more efficient is the animal (Table 1).

Blood test for feed efficiency

Exploiting genetic variation in feed efficiency clearly promises substantial economic benefit. However, the inconvenience and high cost of the 3-month long feed efficiency test required to determine the feed efficiency of a young bull has understandably deterred bull breeders from testing many of their sale bulls. As a consequence, only a few hundred bulls are being tested each year, rather than the many thousand required by commercial cattle producers, if the industry is to make substantial gains in improving feed efficiency. An alternate, less expensive and more convenient test was required.

Insulin-like Growth Factor-I (IGF-I), a protein in blood, is involved in regulation of growth processes and body composition. The PrimeGRO®-LSM (Livestock Selection Method) is a patented Australian technology that uses the level of this protein in blood to predict the genetic merit of farm livestock for feed efficiency and carcass traits. Concentration of IGF-I in blood is moderately heritable (about 0.4; similar to growth rate) and correlated to NFI (0.6; Moore *et al.* 2003). Currently, it is recommended that IGF-I blood samples should be taken at weaning to give the best genetic responses. IGF-I data was used in the January 2004 Angus NFI EBV calculations and had an immediate impact, doubling the number of Angus cattle with an NFI EBV (Fig. 1). Hereford IGF-I data will be used from mid-2004.

Figure 1. EBV for NFI for Angus and Hereford/Poll Hereford cattle (accuracy >19%) and for sires (accuracy >49%). IGF-I data was first used in 2003, in Angus only.

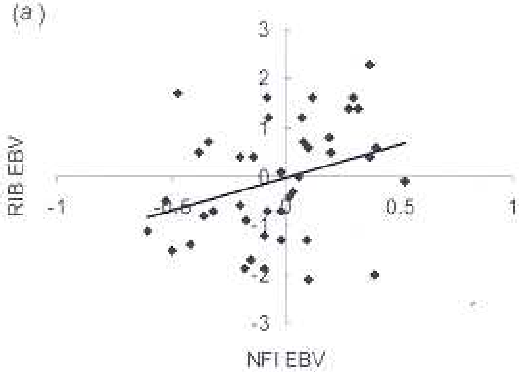


Being an indirect measure of feed efficiency, the IGF-I blood test is not as accurate as conducting a feed efficiency test on a young bull, but is considerably cheaper. It will assist the Australian beef industry to find genetically superior bulls in much greater numbers to produce future generations of feed-efficient cows and steers. However, IGF-I data alone cannot produce an accuracy of 50% or better: this being the level required for an EBV to be published in Breedplan. To achieve higher accuracy some animals need to be tested for NFI.

Relationships with NFI

Fatness and marbling

Evidence exists that there is a genetic relationship between NFI and subcutaneous fat depth, with more efficient (lower NFI) animals tending to be leaner than less efficient animals. Results to date for intramuscular (or marbling) fat (IMF) are not conclusive (Exton *et al.* 2004). Because these relationships are weak, there are bulls that are superior for NFI and a number of desired characteristics. For example, analysis of the Angus 2004 Group Breedplan sire data shows that there are bulls with favourable EBV for NFI, subcutaneous fat and IMF%. Figure 2*a* shows EBV for rib fat and EBV for NFI. Figure 2*b* shows EBV for IMF *versus* EBV for NFI of the same Angus bulls. The figures show



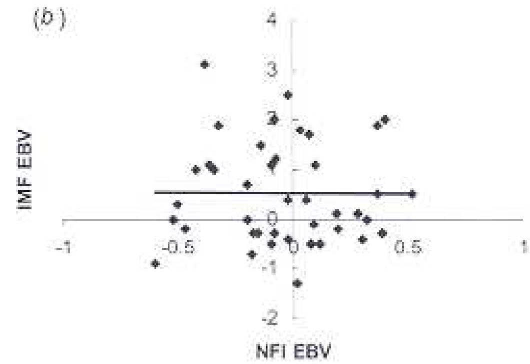


Figure 2. ***(a)*** **Rib fat EBV** ***vs.*** **NFI EBV, and** ***(b)*** **IMF EBV** ***vs.*** **NFI EBV, of Australian Angus bulls from (Exton** ***et al.*** **2004).**

that there are bulls available to Australian beef cattle breeders that are genetically superior for NFI, IMF and subcutaneous fat, being those in the upper left quadrant of each graph. The use of such bulls in commercial breeding programs will make significant gains in efficiency, marbling and profitability in the Australian beef industry.

Efficiency in the feedlot

Divergent selection for low and high postweaning NFI was performed at the NSW Agriculture Research Centre, Trangie, in the 1990s. The final cohort of steer progeny from parents selected for low postweaning NFI (high efficiency) or high NFI (low efficiency) were evaluated for feedlot performance at the CRC for Cattle and Beef Quality "Tullimba" research feedlot, completing their NFI test in August 2003. Results for these steers are summarised in Table 2.

These steers were the result of at least 2 generations of divergent selection on postweaning NFI and the difference of 1.2 kg/day in NFI in the feedlot was larger than for earlier cohorts of Trangie steers with less divergent selection history (Herd *et al.* 2003). The ongoing divergent selection resulted in 11% better FCR by steers of high efficiency parents compared to steers from low efficiency parents, with no adverse effect on growth. Feeding low-NFI steers for slaughter would therefore be more profitable than feeding high-NFI steers. Significant regressions of FCR and NFI with mid-parent NFI EBV provided further evidence for favourable genetic associations between postweaning NFI of the parents and the efficiency of their progeny in the feedlot. The magnitude of the genetic correlations of postweaning NFI with feedlot NFI and FCR are still to be determined but the regression reported in Table 2 indicate that both will be non-zero, positive and favourable.

Steer efficiency on pasture

Most recent evidence for favourable association of steer growth and feed efficiency on pasture with genetic variation in sire NFI is presented by Herd *et al.* (2004). Briefly, in an experiment at Glen Innes, NSW, growth, feed intake and feed efficiency were measured from spring to summer on Angus and Hereford weaner steer progeny of sires with known NFI EBV. Each year, the steers were grown on 3

Table 2. Feedlot performance of steer progeny, born 2001 at Trangie, from parents selected for low postweaning NFI (high efficiency) or high NFI (low efficiency), and regression coefficients with mid-parent EBV for postweaning NFI

	Selection line			Regression with
	High efficiency	Low efficiency	Diff.	parental NFI EBV
Number of animals	61	30		
Start of test weight (kg)	541	533		2.0
Average daily gain (kg/day)	1.53	1.51		-0.01
End of test weight (kg)	646	636		1
Daily feed intake (kg DM/day)	14.0	15.1		1.20 [B]
Feed conversion ratio, (kg/kg)	9.5	10.5	A	0.90 [A]
Net feed intake (kg DM/day)	-0.41	0.83	B	1.16 [B]

[A] Probability values: <0.1. Values are means and regression coefficients.

[B] Probability value: <0.05. Values are means and regression coefficients.

Table 3. Mean initial and final liveweight (LW), average daily gain (ADG), feed intake, net feed intake (NFI) and feed conversion ratio (FCR) of Angus and Hereford steers on pasture in spring to summer of 1995 and 1997, and regression coefficients with sire NFI EBV. Results are for 127 steers from 42 sires (Herd *et al.* 2004)

	Mean	Regression coefficient	Change for 1 kg EBV_{NFI} as % of mean
Start LW (kg)	338	-9	2.6%
ADG (kg/day)	0.84	-0.16 [A]	19%
Final LW (kg)	411	-23	5.5%
Feed intake (kg/day) [C]	8.5	1.3	15%
NFI (kg/day)	0.00	2.2 [B]	26%[D]
FCR (kg intake/kg gain)	10.4	4.2 [B]	41%

[A] $P<0.1$ for regression coefficient differing from zero.
[B] $P<0.5$ for regression coefficient differing from zero.
[C] kg 10 MJ ME/dry matter.
[D] As a % mean daily feed intake.

different pasture systems and pasture intakes were measured twice using the alkane technique. Significant ($P<0.05$) regression coefficients for steer performance traits against sire NFI EBV is evidence that genetic variation in NFI was associated with phenotypic variation in steer performance on pasture. Initial and final liveweight of the steers, and feed intake, were not associated with variation in sire NFI EBV ($P>0.05$; Table 3). However, daily gain by the steers tended ($P<0.1$) toward a favourable negative association with sire NFI EBV. NFI and FCR had positive associations ($P<0.05$) with sire NFI EBV. The results show that 1 kg/day lower NFI EBV of a sire produced steer progeny that grew 19% faster, with no increase in feed eaten, had a 26% lower NFI, and a 41% better FCR.

In a previous experiment (Herd *et al.* 2002), steer progeny of low and NFI Angus parents were evaluated for yearling growth and efficiency over a dry summer period at Glen Innes. During this period, the low pasture availability restricted average growth rates to 0.46 kg/day. Low NFI steers (high efficiency parents) ate less than high NFI steers (low efficiency parents), grew faster, and had a much better FCR. Low NFI steers grew at 0.50 kg/day compared with 0.42 kg/day by high NFI steers (20% faster), consumed 3.04 kg/day compared with 3.23 kg/day (6% less) and had a FCR of 6.4:1 compared with 8.5:1 (25% better).

Cow efficiency on pasture

The efficiency at pasture of lactating cows has been examined and, although only a small experiment, the benefit of breeding for low NFI is apparent. Pasture intake was measured in 41 lactating cows at the NSW Agriculture Research Centre at Trangie (Herd *et al.* 1998). The cows had been tested as young heifers on a pelleted ration and grouped as either high efficiency (HE) or low efficiency (LE) based on their own postweaning NFI test result. The cows were in the third month of their lactation and grazing an irrigated oat crop. Pasture feed intake of the cows was measured by the alkane technique. The experiment found both phenotypic and genetic association between NFI measured on the young female and her later efficiency at pasture. The HE cows were 7% heavier ($P<0.05$) than the LE cows, but consumed no more pasture per day, and on this basis were more efficient (Table 4). The HE cows had similar subcutaneous fat stores and had calves of similar weight to LE cows. The advantage in efficiency of HE cows, when expressed as a ratio of calf weight

Table 4. Cow and calf liveweights, pasture intake and efficiency for lactating cows that had previously been tested for postweaning NFI and ranked as high (HE) or low (LE) efficiency, and regression coefficients with their NFI EBV

	HE cows	LE cows	Diff.	Regression with NFI EBV
Number of cows	20	21		
Cow LW (kg)	618	577	A	-35
Cow rib fat (mm)	12.0	11.7		-0.5
Calf LW (kg)	111	104		-2
Cow DM-intake (kg/day)	12.5	13.2		1.4
Calf LW/cow DM-intake (kg/kg/day)	9.3	8.1	B	-1.20

[A] $P<0.05$ for means and regression coefficients.
[B] $P<0.01$ for means and regression coefficients.

to cow feed intake, whilst numerically large (15%), was statistically non-significant (P=0.07).

These results show that heifers which were either high or low efficiency when tested as weaners on a medium quality ration tended to also be high or low in efficiency 2 years later as lactating cows on pasture. The statistically significant regression coefficient for cow efficiency on pasture with postweaning NFI EBV is evidence for genetic association between efficiency of the young heifer and efficiency of the lactating cow. Selecting cattle with lower NFI EBV can be expected to produce more feed-efficient daughters on pasture.

Cow reproductive performance

So far there is no evidence for an unfavourable association between postweaning NFI and reproductive performance of cows. The effect of divergent selection for NFI on maternal productivity was examined using records on 185 females at the NSW Agriculture Research Centre, Trangie (Arthur and Herd 2004). There were no significant selection line differences in calving rate (mean of 94%), weaning rate (mean of 88%), milk yield (mean of 8.2 kg/day) and weight of calf weaned per female exposed to bull (mean of 188 kg). The study indicated that after 1.5 generations of divergent selection for NFI there had been no significant selection line differences for maternal productivity traits.

Further reading

A Special Edition of *Australian Journal of Experimental Agriculture* entitled "Improving Efficiency of Feed Utilisation by Animals" (Volume 44 Number 4-5) is to be published mid-2004. This includes a number of review papers and papers presenting the most recent results from Australian feed efficiency research.

Conclusion

This paper presents evidence for genetic variation in feed efficiency in beef cattle. When measured as NFI, selection for improved feed efficiency, can be expected to produce steer and heifer progeny that require less feed at pasture or in the feedlot, with no compromise in growth, carcase or reproductive performance. An EBV for NFI is now available within the Angus, Hereford and Poll Hereford breeds. As more bulls that are genetically superior for NFI are bred by the seedstock sector and used widely in commercial beef production, significant savings in feed costs can be expected. Incorporating genetics for feed efficiency will need to be in balance with genes for carcass traits and cow herd productivity.

As cattle in a commercial herd become more feed efficient over time, some new management options arise. The cattle manager can choose to increase the number of stock on the same area of land as used previously for the unimproved herd, since each animal is eating a little less. Alternatively, the same number of stock could be maintained on a smaller area, or on the same area but with an effective reduction in stocking rate and pressure as each animal is eating less. The faster growth of steers on pasture may allow them to reach target weights before seasonal declines in pasture quality and quantity would otherwise require supplementation, or allow the steers to be grown to heavier weights than previously.

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