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Selection for Growth and Feed Efficiency – The Australian Experience

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Abstract

Profitability in beef production is influenced by a number of traits, including growth and feed efficiency. This paper reviews key Australian selection experiments on growth and feed efficiency, and the beef industry adoption of selection for these traits. Response to selection for growth has been demonstrated by a divergent selection experiment. Five generations of divergent selection for growth resulted in 19% divergence in yearling weight and 18% in weaning weight, and no effect on carcass composition at maturity. Selection for growth in industry herds started in the 1980s, with a steady rate of genetic gain being achieved. In Australian Angus seedstock population, for example, the annual genetic gain in estimated breeding values (EBVs) for 400-day weight was 0.15 standard deviation units from 1998 to 2003. As with growth, selection for feed efficiency has been demonstrated by a divergent selection experiment for residual feed intake (RFI). Two generations of selection produced an annual divergence of 0.25 kg/day of 10MJ ME feed with no correlated responses in growth and meat quality of young cattle. Cow weight and reproduction were not affected, however, High RFI cows tended to have higher subcutaneous fat depth relative to Low RFI cows. Testing for RFI in industry herds started in 1996, and from 2002, RFI EBVs are provided for seedstock Angus and Hereford cattle. Several studies have indicated substantial economic benefit from selection for low RFI, however the initial high cost of testing to identify superior animals is an impediment to industry adoption.

Introduction

Beef cattle breeders world-wide place considerable emphasis on selection for growth. It is relatively easy to measure, and is closely related to profitability of beef enterprises, especially under feedlot conditions (Dickerson et al., 1974). Also related to profitability is feed cost. Providing feed for cattle is the single largest input cost in most livestock production enterprises (Schmidt et al., 2001). Hence improvement in the efficiency of feed utilisation is essential in reducing production cost. The objective of this paper is to review key selection experiments in beef cattle in Australia on growth and feed efficiency and the adoption of selection for these traits in the beef industry.

Selection for growth

In the early 1970s beef producers in Australia began to place considerable emphasis on selection for growth and size. While it was known that selection for growth rate would result in faster growing and heavier animals, there was little information on the expected changes in other economically important traits such as reproductive performance, milk production, carcass quality and other components of herd profitability. To complement the cattle experiments already in progress (listed in the review by Mrode, 1988), selection experiments were set up in Australia and New Zealand (listed in the review by Parnell and Morris, 1994) in the 1970s to address some of these issues under pasture conditions.

Divergent selection for growth rate at Trangie

An experiment to evaluate the effects of selection for yearling growth rate (average daily gain from birth to yearling age) on the major components of herd profitability was conducted at the Agricultural Research centre at Trangie, Australia from 1973 to 1992. Two divergent selection lines (High line and Low line) and an unselected Control line were created in a closed Angus herd. Seventeen years of selection resulted in 5.5, 5.0 and 5.1 generations of selection for High, Control and Low lines, respectively. The rate of inbreeding (0.74% for High line, 0.53% for

Control line and 0.88% for Low line) was low due to the high effective population sizes of 67, 106 and 71 per generation for High, Control and Low selection lines, respectively. Average selection differentials per year were 0.016 kg/day and -0.018 kg/day for the High and Low selection lines, respectively, resulting in a corresponding direct selection response per year of 0.006 kg/day and -0.007 kg/day. Using animals recorded prior to 1964 as the base, the mean estimated breeding value (EBV) for yearling growth rate at the start of the experiment (1974) was calculated to be 0.015 kg/day. After 17 years (1991) of selection, average yearling growth rate EBV for High line calves was 0.115 kg/day, compared to 0.030 kg/day for the Control line and -0.060 kg/day for the Low line calves. Realised heritabilities for yearling growth rate were 0.37 ± 0.09 for the High line and 0.38 ± 0.09 for the Low line (Parnell et al., 1997). These results are also in agreement with expectations from published genetic parameters as reviewed by Koots et al. (1994a,b).

The annual correlated responses in calf growth traits up to yearling age are presented in Figure 1. Control Line means for birth weight, weaning weight, and the weight, height, girth, length, pelvic area and scrotal circumference at yearling age were 31 kg, 197 kg, 274 kg, 102 cm, 153 cm, 129 cm, 185 cm^2 and 33 cm, respectively (Arthur et al., 1997). Mature weight (kg) and height (cm) of cows were 540 ± 6 kg and 119.3 ± 0.7 cm for the High Line, 497 ± 6 kg and 115.7 ± 0.7 cm for the Control Line, and 418 ± 6 kg and 108.3 ± 0.6 cm for the Low Line. No significant differences between the lines were found in rate of maturation of weight, height and girth (Archer et al., 1998b). These positive responses to liveweight at all ages are in agreement with other selection experiments reviewed by Mrode (1988). In a serial slaughter study, the mean mature empty body weight (body weight minus urine and gut content) was 666 ± 17 kg, 588 ± 18 kg and 512 ± 16 kg for High, Control and Low line steers, respectively. However, no significant selection line differences were obtained in carcass composition at maturity (Perry and Arthur, 2000). These results indicate that selection for yearling growth rate leads

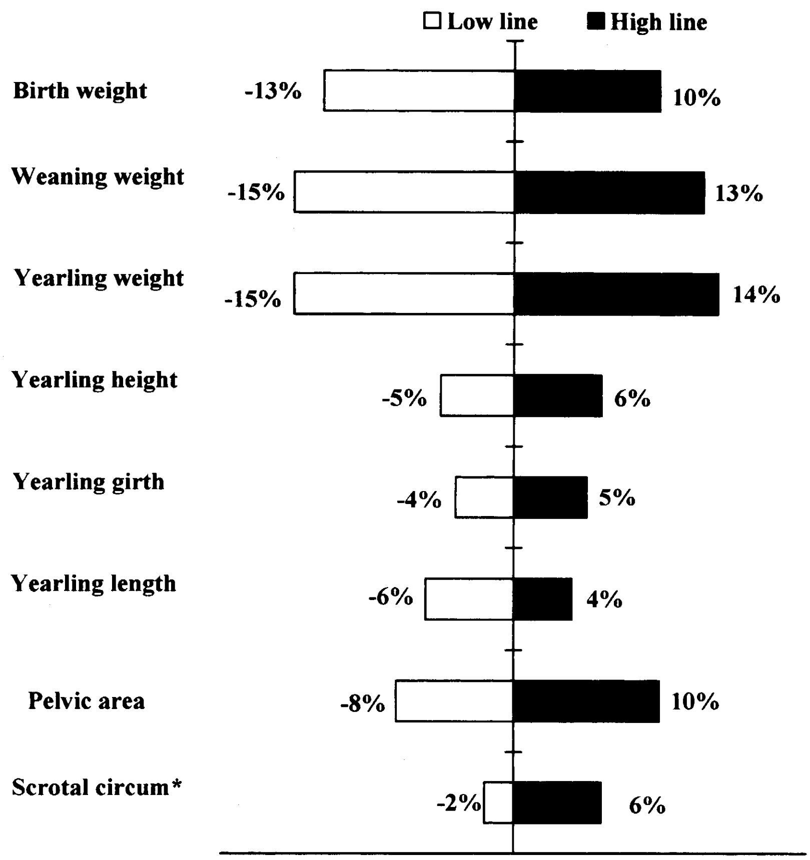

Fig. 1. Correlated responses to selection for yearling gain, as deviations from Control Line means. *Denotes scrotal circumference. [Arthur et al., 1997].

to a change in body size at all ages but no change in body composition at maturity. Recent analyses of data from about 4,000 cattle indicate favourable genetic associations between growth rate and several meat quality traits of cattle in temperate Australia (Reverter et al. 2003).

Heifers from the High Line reached puberty at a younger age (324 days) than Control Line heifers (336 days), who in turn reached puberty at a younger age than Low Line heifers (355 days). Cows from the High line had similar reproductive rates (per cow mated), at calving (86%) and at weaning (83%) compared to the Control Line (means of 84% and 78%, respectively), while the Low Line (means of 77% and 69%, respectively) cows had significantly lower reproductive rates (Archer et al., 1998a). Similar responses in reproductive rates were obtained in a High and Control growth rate selection experiment in New Zealand (Morris et al., 1992). These results show that selection for high growth rate did not compromise reproductive performance.

Application in industry - Growth

BREEDPLAN is a genetic evaluation system for beef cattle, for Australia, New Zealand and other international countries. It generates EBVs for growth, carcass, fertility and calving ease trait complexes of animals from performance recorded seedstock herds of all the major cattle breeds (Graser et al. 2005). BREEDPLAN EBVs for growth traits have been available since 1985. Initially all available Australian data were used to generate genetic parameters (Meyer et al., 1990; Meyer 1994) that underpinned BREEDPLAN evaluations. Figure 2 shows the rate of genetic gain in EBVs for Australian Angus cattle over four periods from 1980 to 2003 (Barwick and Henzell, 2005). It shows a clear trend of increasing rate of genetic gain in 200-day and 400-day weights. The rate of genetic gain in birth weight increased in the first two periods (1980-85) but declined during the last two periods (1992-2003). The changes observed in the industry rate of genetic gain reflect the improved ability of seedstock breeders, over time, to select for other traits at the same time as selecting for growth. The uptake of multi-trait selection for economic merit was enhanced by the development of the selection index program, BreedObject, and the subsequent release of the "BreedObject on the web" version (www.breedobject.com).

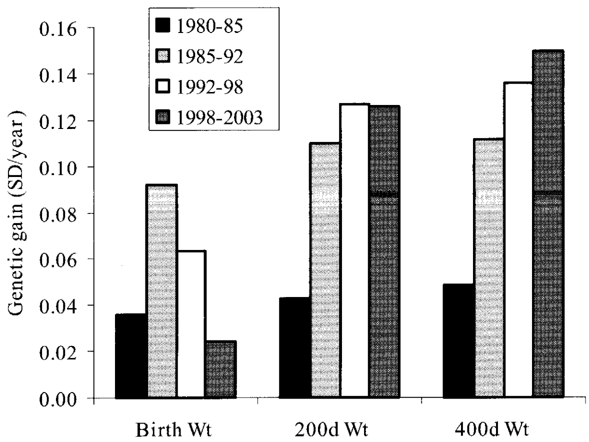

Fig. 2. Rate of genetic gain in growth in estimated breeding values for growth in Australia Angus over four periods: 1980-85 (pre-BREEDPLAN), 1985-92 (early BREEDPLAN – growth traits only); 1992-98 (BREEDPLAN – growth, carcass and fertility); 1998-2003 (BREEDPLAN and Selection indexes). [Adapted from Barwick and Henzell, 2005]

Selection for feed efficiency

The importance of feed efficiency to profitability in beef production is obvious. However, measuring individual animal feed intake is difficult and expensive, and this constraint has been responsible for the paucity of research into genetic variation in feed intake and efficiency. With recent advances in computing and electronics, reliable automatic feed intake recorders have been developed which make it easier to measure feed intake. This has resulted in renewed interest in research in this area.

Feed intake is correlated with liveweight and level of production. Hence to relate feed intake to production system efficiency, several feed efficiency traits have been developed over the years. These traits include feed conversion ratio (FCR), partial efficiency of growth, maintenance efficiency, efficiency of lactation and residual feed intake. The definitions, computational formulae and the relationships among the feed efficiency traits and with growth traits have been reported by Arthur et al. (2001b). Residual feed intake (RFI) is defined as the difference between an animal's actual feed intake and it's expected feed intake, based on it's size and level of production (eg. growth rate in beef cattle). Residual feed intake is phenotypically independent of size and level of production, and it is fast becoming the trait of choice in studies on efficiency of feed utilisation.

There have been three major integrated projects in Australia since 1993 on feed efficiency. They are the Trangie, Beef CRC I, and Beef CRC II projects, and have been described by Arthur et al. (2004). The projects include a divergent selection experiment and the generation of data for estimation of genetic parameters.

Divergent selection for feed efficiency at Trangie

An experiment to evaluate the effects of selection for postweaning RFI in Angus cattle was started in 1993 at the Agricultural Research Centre at Trangie, Australia. It was the first RFI single-trait selection experiment in beef cattle in the world. Starting with the 1993-born animals, two divergent selection lines were created: the Low RFI (more efficient in feed utilisation) and High RFI (less efficient in feed utilisation) selection lines. Five years of selection (ending with the 1999-born animals) resulted in 1.73 and 1.96 generations of selection for the Low and High RFI lines, respectively. The inbreeding rate was low (0.6% for dams and 1.6% for calves) due to the high effective population sizes of 42 and 43 per generation for the Low and High RFI lines, respectively. Average selection differentials per year were -0.318 kg/day and 0.387 kg/day for the Low and High RFI lines, respectively, resulting in a significant average annual response (divergence between the lines) of 0.249 kg/day of feed with 10 MJ ME (Arthur et al., 2001a). During the period of study the cost of feed was $200 per 1000 kg, hence the divergence between the selection lines in the 1999-born progeny (1.247 kg/day) represents savings of $27 in feed costs per animal over a 100 day feeding period. Mean EBV for RFI for the 1993 foundation animals were used as the zero base (Fig. 3), and by 1999 the means were 0.562 kg/day and -0.508 kg/day for the High and Low RFI lines, respectively.

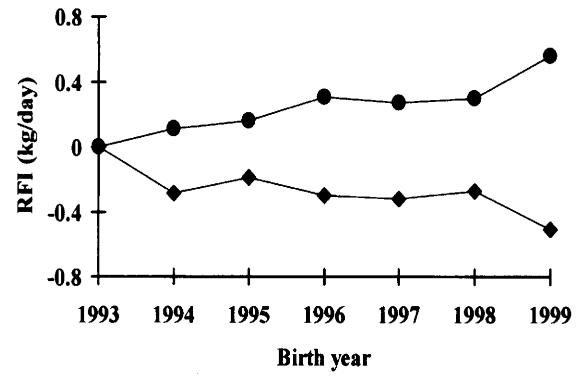

Fig 3. Trends in estimated breeding values for residual feed intake (RFI) for Low (♦) and High (●) RFI selection lines [Adapted from Arthur et al., 2001a]

Correlated responses in yearling weight (mean of 383 kg) and average daily gain (mean of 1.4 kg/day) were not significant. However, the annual correlated response of 0.24 kg/day for feed intake (mean of 10 kg/day) and 0.24 for FCR (mean of 7.2.) were significant (Arthur et al., 2001a). These results indicate that selection for low RFI results in improvement in postweaning efficiency of feed utilisation with minimal effect on growth.

The 1997-, 1998- and 1999-born females were used to study the effect of divergent selection for RFI on maternal productivity across three mating seasons, starting from 2000. Rib fat depth on the cows was measured by ultrasound at the start of mating season and six months later at the weaning of their calf each year. Differences in fatness were not significant except for those measured at the start of the 2000 (10.8 ± 0.4 mm *v.* 9.3 ± 0.4 mm), 2001 (11.3 ± 0.4 mm *v.* 9.8 ± 0.4 mm) and 2002 (7.0 ± 0.5 mm v. 5.7 ± 0.5 mm) mating seasons, where High RFI cows had significantly higher rib fat depths. There were no selection line differences in cow weight (measured four times a year), pregnancy (mean of 90.4%), calving (mean of 88.7 %) and weaning (mean of 80.8 %) rates, milk yield (mean of 7.7 kg/day) and weight of calf weaned per cow exposed to bull (mean of 195 kg). These results indicate that after 1.5 generations of divergent selection for residual feed intake there are no significant selection line differences for maternal productivity traits (Arthur et al., 2005). Feed intake was not measured during this study, however results from an earlier study on mature cows (Archer et al., 2002) suggests that the Low RFI cows would have consumed less feed relative to the High RFI cows.

Application in industry – Feed Efficiency

By 1996, there was interest by the Australian beef industry to test animals for feed efficiency, and a number of centralised test stations have developed across southern Australia. A Standards Manual, with detailed procedures for feed efficiency testing, was developed, and test stations were required to be

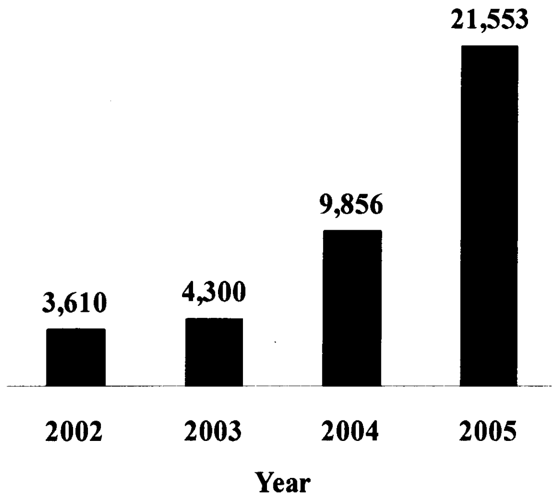

Fig.4. Number of Angus cattle with estimated breeding values for residual feed intake.

accredited before data can be used in BREEDPLAN. By 2002, there were enough data collected on industry animals for BREEDPLAN to start providing EBVs for RFI (also known as net feed intake or NFI in the industry). From 2004, plasma concentration of insulin-like growth factor-I (IGF-I) was included in the generation of the NFI EBVs (Moore et al., 2005). The number of cattle (Angus and Hereford breeds) with EBVs for RFI is shown in Figure 4.

Genetic parameters for feed efficiency

A comprehensive review of information available pre-1996 on the genetics of feed efficiency in cattle was provided by Archer et al. (1999), and subsequent new information was included in the review by Arthur et al. (2004a). Recent studies by Robinson and Oddy (2004) and Schenkel et al. (2004) have provided additional genetic information. These results have been confirmed in Japanese Black (Wagyu) bulls in a recent publication by Hoque et al. (2005). All the reviews and major studies highlight the existence of genetic variation in feed efficiency and the fact that most feed efficiency traits are moderately heritable, hence the potential for genetic improvement. Whereas there is some information on the genetic relationships between carcass and meat quality traits with FCR (Koots et al. 1994b), information on their relationship with RFI is limited. Genetic correlations have been reported between RFI and carcass lean percentage of 0.17 by Jensen et al. (1992) and -0.47 by Herd and Bishop (2000); and between RFI and subcutaneous rib fat of 0.48 by Robinson and Oddy

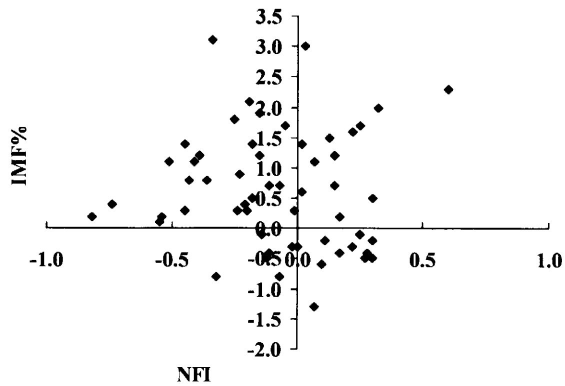

Fig 5. Estimated breeding values for intramuscular fat (IMF) and net (residual) feed intake of industry Angus bulls in Australia.

(2004) and 0.30 in Wagyu cattle by Hoque et al. (2006). The differences among the studies, in the value of the genetic correlations may be due to the maturity level at which the RFI and the fatness were measured. Results on cattle, after 1 generation of divergent selection, for RFI indicate that there is no correlated response in meat tenderness (shear force) and marbling (McDonagh et al. 2001). However, Hoque et al. (2006) have reported a favourable and moderate genetic correlation between RFI and marbling in Wagyu cattle. Data from the 2005 Angus BREEDPLAN analysis indicate a significant number of bulls which have low EBVs for NFI (high efficiency) and high EBVs for marbling (Fig 5; Exton 2005, per. comm.).

Challenges to adoption of feed efficiency technology

The high cost associated with the identifying cattle that are superior for feed efficiency is the major impediment to adoption. Simple, low-cost alternatives need to be developed. Although physiological markers like plasma IGF-I do help, gene markers for feed efficiency, if discovered will go a long way to improve adoption. Although there are studies world-wide to find such genes, few results have been published. Pitchford et al. (2002) reported five QTL for feed intake and efficiency in cattle. Recent studies have shown associations between polymorphisms in the leptin gene and feed intake and energy balance in dairy and beef cattle (Liefers et al. 2002, Nkrumah et al. 2004a, 2005).

Benefits from selection for feed efficiency

A number of comprehensive economic analyses on the benefit of selection for feed efficiency, based on RFI, have been conducted, and all indicate that in spite of the high cost of testing for feed efficiency, the economic benefits to the individual producer and to the beef industry is substantial (Exton et al., 2000; Archer et al., 2004; Wood et al., 2004). In addition to the economic benefits, recent studies have highlighted the potential to use selection for RFI as a greenhouse mitigation strategy. Studies by Nkrumah et al. (2004b) and Hegarty et al. (2005) indicate that methane production from Low RFI steers was approximately 6-8% lower than those from High RFI cattle.

Gaps in knowledge

There are clear gaps in our knowledge which need to be filled. Most of the information currently available is on the growing animals. There is the need for knowledge of the phenotypic and genetic relationships of feed efficiency in different parts of the production system with all other economically important traits. There is also the need for information on possible interactions of feed efficiency with different levels of feed quantity and quality. Related to this is the lack of information on genotype by environment interactions on feed intake and efficiency. Finally there is a need for information on non-additive genetic effects, such as heterosis, on feed efficiency.

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