Lifting beef industry productivity through genetic improvement – progress and challenges in a changing climate

Steve A. Barwick
Animal Genetics and Breeding Unit, Armidale NSW 2351 (a joint venture of Industry & Investment NSW and the University of New England)
steve.barwick@industry.nsw.gov.au

Abstract: Beef breeding needs to respond to numerous challenges if it is to help lift industry productivity in the face of likely declines in the production environment and other pressures. A brief summary of some of the key challenges is presented here against the background of the genetic trends that are occurring within and across the industry's breeds. During the past decade there has been a major shift in industry focus from single traits towards genetic selection for overall merit. Favourable genetic changes are occurring at an increasing rate across multiple traits and in overall merit across most breeds. These changes are sometimes large, for example, in the Angus breed. Nevertheless, there is the potential, and need, for rates of genetic gain to be much greater. Inadequacies of performance recording still limit what can be achieved in many breeds. Key challenges exist in molecular genetics, in integrating genetics and management improvements, and in genetic selection confronting both environment change and the potential cost of methane emissions. Perhaps the biggest challenge will be for industry to maintain the needed focus on improving overall productivity in the face of potentially many new pressures to consider single issues.

Keywords: beef breeding, production environment, genetic trends, performance recording.

Introduction

The world faces not only climate change but also the potentially greater threat of food shortage as the environment declines (Cribb 2008). This makes it critical that agricultural productivity lifts in the face of climate change.

Beef, the largest agricultural export of New South Wales (NSW Department of Primary Industries 2009), faces particular challenges. Beef cattle are large emitters of greenhouse gas, increasing pressures on land use mean cows are likely to need to perform in less favoured environments, and it is expected this latter trend will markedly increase under climate change.

Beef cattle breeding needs to respond to these challenges. This paper presents a brief summary of genetic improvements in productivity that are occurring in the industry and some key challenges that will need to be confronted.

Measuring genetic change in the industry

Estimated breeding values (EBVs) are the basic industry measures of genetic differences among seedstock. Over time, EBVs available through BREEDPLAN have come to encompass the growth, carcass, fertility and calving ease trait complexes (Graser et al. 2005); and in some breeds trial EBVs for net feed intake, docility, structural soundness and very recently a DNA marker-based EBV for meat tenderness (Johnston et al. 2009). Over the past decade, $Indexes have become the accepted measure of genetic differences in overall breeding value for multiple trait merit (Barwick and Henzell 2005).

EBVs from a BREEDPLAN analysis are derived not only for currently active animals but also for all earlier-born and related animals in the database of the breed involved. Because the EBVs are directly comparable across all animals in the analysis, the breed's genetic trend can be assessed from the means for animals born over different years. Trends calculated for Angus, expressed in absolute units, are shown in Figure 1.

We are also usually interested in the rate of genetic change in a trait (the slope of the trend curve) at a particular time, or over an interval. To facilitate comparison across traits and breeds, and possibly across species, the rate of change may be expressed in standard units (see Figure 2). A suitable standard unit is the trait genetic standard deviation, as that allows comparisons between traits on an equal basis with respect to the amount of genetic change that was possible (Barwick and Henzell 2005; Swan et al. 2009).

Evidence of favourable genetic changes occurring across multiple traits

Figure 1 shows the numerous favourable genetic changes that have occurred across multiple traits in Angus since the introduction of BREEDPLAN in 1985 and particularly since the early-to-mid 1990s when genetic evaluation started to include traits other than growth. According to the Angus breed website there are now more Angus bulls sold in Australia than bulls of any other breed (http://www.angusaustralia.com.au/M_Bull_Nat_Summ.htm). At the same time as growth (e.g. 600d liveweight) has increased by more than 65 kg in Angus (Figure 1a), intramuscular fat % (in a 300 kg carcass) has increased by about 1.5%, eye muscle area by about 3 cm^2, and days from bull-in to calving (reflecting both improved calving rate and earliness of calving) has decreased by about 3 days (Figures 1b and c). There have also been other favourable changes. Calving ease, for example, initially declined as growth potential increased, but it has since also improved despite further increases in growth (Figures 1a and c).

Figure 2 shows rates of genetic gain in the same Angus traits using time intervals that correspond to developments in BREEDPLAN. Rates of gain have generally increased over time and in line with the availability of the different EBVs and $Indexes. Rates of gain have been higher in growth traits than in other traits, and have noticeably slowed for birth weight and mature cow weight over the last two time intervals. Rates of gain in IMF% and EMA have been greater over the last two time intervals; and rates of gain in calving ease have increased despite birth weight still increasing to some extent with other growth.

Shifting the focus to overall merit

The overall objective for breeding is to lift production system productivity at the economic level, and one of the main achievements of the past decade has been to shift the focus of the industry from single traits towards selection for such an expression of overall merit. $Index availability and adoption has been instrumental in this. $Indexes reflect differences in expected total returns net of management costs and feed costs for the described production system (Barwick and Henzell 2005). The unit of the $Index is $ per cow, but because the calculations account for feed requirement and allow feed availability level to be unchanged, selection on $Index is also selection for $ per ha.

$Index applications have been mostly at breed level for breeding objectives customised for the main production systems of each breed. In Australia, some 31 $Indexes have been implemented across the major breeds, and the production systems addressed by these represent about 90% of the national cow herd. Similar applications internationally have grown to the point where there are also about an equivalent number of further $Indexes adopted overseas, including for many of the major breeds of New Zealand, the UK, Argentina, and South Africa.

$Index use is supported by the BreedObject website (http://breedobject.com), where there are more than 1400 registered users. Website users also have the opportunity to develop their own objectives and $Indexes, and to rank animals on $Indexes used in other countries (Barwick et al. 2007) to assist in evaluating semen and seedstock for import or export.

Evidence of genetic improvement of overall merit

The rates of genetic gain in overall merit occurring in some major breeds (Angus, Brahman, Charolais, Hereford, Santa Gertrudis) are shown in Figure 3. Rates of gain are larger in Angus than the other breeds. Breeds commonly are at different stages in their performance recording, EBVs available, and introduction or revision of the breeding objectives underlying their $Indexes. The rates of gain occurring in overall merit need to be much greater, as commented on by others (e.g. Parnell 2008).

There is plenty of potential for that to occur. Goddard (2001) nominated a ballpark figure of 0.15 genetic standard deviations as achievable for most rates of gain. There are a number of possible explanations for the recent slowing in the rate of increase in gain in Angus (Figure 3). It could reflect the typical slowing in rate of increase that is often seen with adoption; or it may be partly the result of recent breed revisions of $Indexes, or method refinements for importing overseas information into BREEDPLAN. The average increase in the Long Fed/CAAB $Index of Angus over the 2003 to 2008 interval represents $4.27 per cow per year. A rate of gain many times greater than that is occurring in some herds where there is a lot of scope for improvement. Also, among the herds with higher mean performance improvement, some have rates of gain of more than $7 per cow per year (0.20 genetic standard deviations).

Some key challenges

Molecular genetics

Researchers and others have placed much store in molecular genetics being the source of better, earlier and simpler performance measures that could boost genetic gains, especially for key traits that can’t otherwise be measured. Results so far have not been very encouraging. A summary of Beef CRC results is available at http://www.beefcrc.com.au/Aus-Beef-DNA-results. DNA markers with large effects appear quite rare, and predictions using associations with the small effects of many single nucleotide polymorphisms (SNPs) appear problematic. Closer attention needs to be paid to trait definition and to definition of the populations in which any effect is expected to be realised. The promise of molecular advances also presents other challenges (Banks et al. 2009). Included in these is its capacity to distract industry from the performance recording effort that continues to be needed; and to distract selection from the needed focus on overall rather than single trait merit.

To reduce this risk, molecular sources of information that are identified as useful will need to be incorporated in $Indexes as quickly as possible.

Integration of genetics and management

As productivity gains become more difficult to achieve, for example as the animal's environment declines, it will be more important for genetic and management improvements to be considered jointly. Figure 4 illustrates some of the inter-dependencies. An increased feed requirement per head generally accompanies genetically increased total productivity (assuming no increase in feed efficiency), so the curve for 'improved genetics' moves upwards and to the left (see Figure 4). If the current stocking rate is too low, using improved genetics has the added benefit of lifting feed utilisation. If current stocking rate is high, perhaps at an optimum, the benefits from using improved genetics may only be fully realised if it is recognised that the stocking rate also has to change. The benefits of genetic improvement are thus dependent to an extent on management, and this dependence in the future is likely to be more critical.

Environment change

As resources available to animals become limiting there is potential for animals to re-rank for their performance. Genotype-by-environment interactions that result in re-ranking are not very evident for single traits (Jeyaruban et al. 2009; McGuirk 2009), but they are thought to be more of an issue for reproduction and overall productivity. Jenkins (2009) gives an example of the re-ranking of cow genotypes. Interactions are likely to be more evident when the change to the animal's environment puts it outside what would be a 'normal' range (James 2009). It may be that under climate change cows in the future will be confronted by environments outside their normal range. Either way, the challenge for genetics is to understand how variances and trait relationships change with environment level so that selection for a lower (and possibly more variable) environment level can be effective. There is a particular need for earlier and more effective genetic evaluation for reproduction traits. This need is already especially apparent in the tropically adapted Brahman, where net reproductive rate is low.

Methane

Genetic improvement can contribute to reducing beef cattle methane by increasing productivity, and potentially also by direct selection (Cowie and Fairweather 2008). Productivity increases can mean that fewer animals are required. Direct selection poses the most challenge, but is necessary if genetic relationships between methane output and production traits are to be manipulated. Herd and Hegarty (2008) discuss the possibility of net feed intake being an effective indirect criterion. Current measures of overall merit can be improved by costing the methane that is expected to be associated with the feed intake needed for production. Costing this against the different production traits of the breeding objective is a likely first approach to accounting for methane in breeding. It presupposes the existence of a basis (e.g. emissions trading) for the costing. $Indexes for breeding objectives derived in this way would account for the genetic variation in methane emission associated with production traits, but would not account for the variation that might be independent of the production traits.

There has been some discussion of the criterion that should be used to measure methane abatement (e.g. Cowie and Fairweather 2008). In beef, for example, emissions could be measured per animal, per unit of product or per unit of feed. It is worth noting that the criterion chosen will not in itself change the breeding objective. A recent policy report (ACIL Tasman 2009) highlighted that whether or not emissions actually increase despite higher emissions efficiency (theoretically possible) will be best determined "by competition within economy-wide markets that sensibly value emission effects". Consistent with this, it is expected that methane emission will become a part of the breeding objective, but its importance to the overall objective will be determined in the same way as it is for other traits—from its genetic variance and assessed economic value (cost) to the production system.

Conclusions

Numerous favourable genetic changes are occurring in the beef industry, and at rates that are increasing both for multiple individual traits and for $Indexes of overall merit. There is potential for rates of gains to be much greater. Across the industry there have been important shifts in focus from single traits to overall merit. There is a need for greater selection intensity and in many breeds for increased performance recording so selection can be more effective.

Molecular genetics offers the promise of new selection criteria, but this still seems some way off. There is a risk of distracting industry selection from the needed focus on overall, rather than single trait merit. It is important that molecular sources of information that are identified as useful are incorporated in $Indexes as quickly as possible.

Environment change is a challenge to both genetics and management, and they increasingly will need to be considered together. It is expected that methane emissions will be included in breeding objectives as the mechanism for carbon costing becomes clearer. There are numerous significant challenges ahead for beef genetic improvement, but perhaps the biggest challenge will be for industry to maintain its focus on lifting overall productivity in the face of many potentially conflicting messages.

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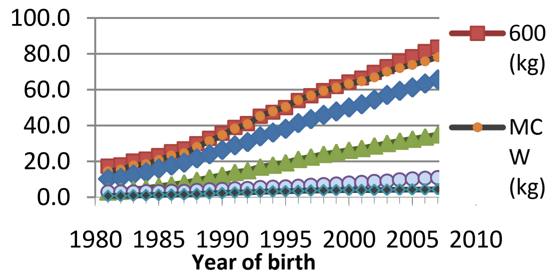
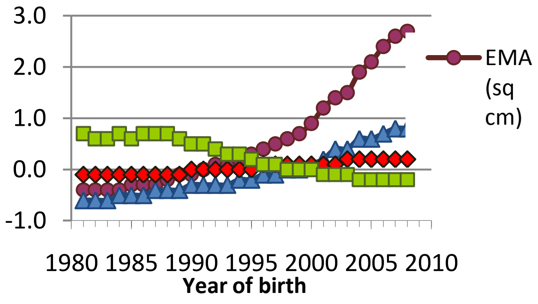
Appendix

Figure 1. Genetic trends in traits and $Indexes in Angus, expressed in absolute units

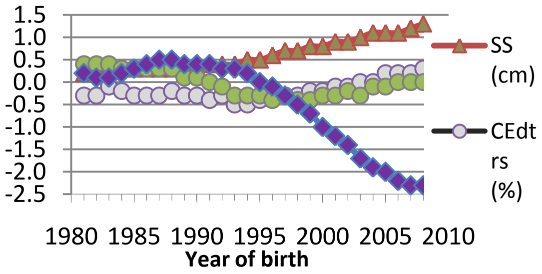
a) Growth traits



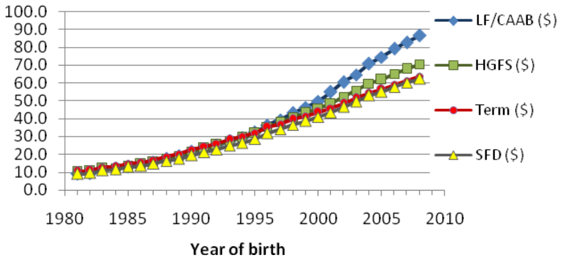
b) Carcass traits (at 300 kg carcass weight)



c) Fertility and calving ease traits



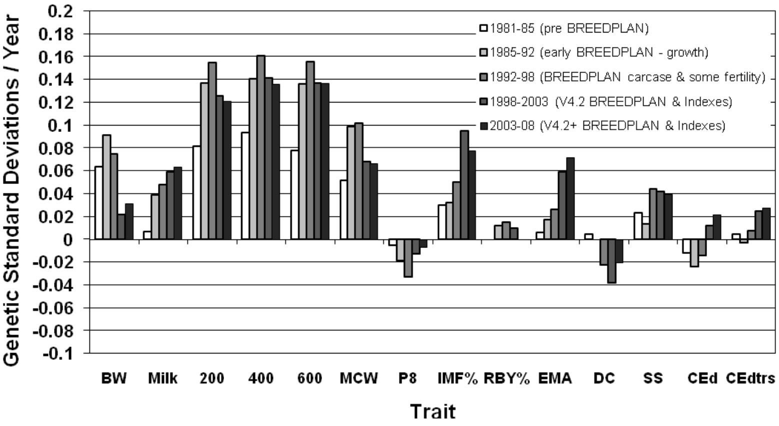
d) $Indexes



Based on June 2009 Angus Group BREEDPLAN (Trans-Tasman) analysis

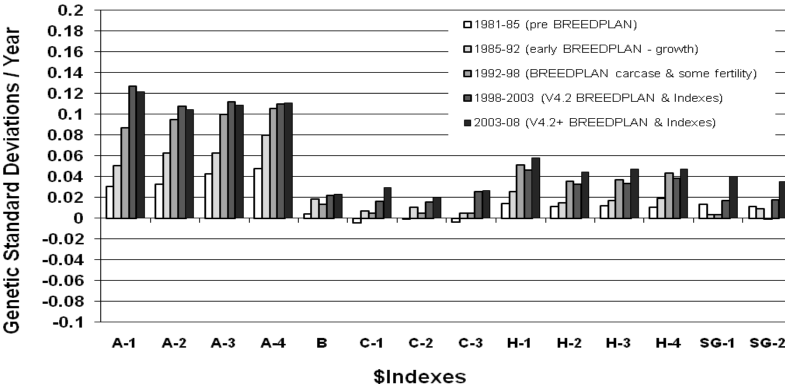
BW: birth weight; Milk: 200d liveweight (maternal); 200: 200d liveweight (individual); 400: 400d liveweight; 600: 600d liveweight; MCW: mature cow liveweight; P8: rump fat depth; IMF%: intramuscular fat %; RBY%: retail beef yield %; EMA: eye muscle area; DC: days to calving; SS: scrotal size; CEd: calving ease (individual); CEdtrs: calving ease (daughters); LF/CAAB: Long Fed/CAAB; HGFS: Heavy Grass Fed Steer; SFD: Short Fed Domestic; Term: Terminal

Figure 2. Rates of genetic gain over specific time intervals for individual traits in Angus, expressed in trait genetic standard deviations



See Figure 1 for trait abbreviations

Figure 3. Rates of genetic gain over specific time intervals in $Indexes of some major breeds, expressed in breeding objective genetic standard deviations



A-1: Angus Long Fed/CAAB; A-2: Angus Heavy Grass Fed Steer; A-3: Angus Short Fed Steer; A-4: Angus Terminal; B: Brahman Jap Ox; C-1: Charolais Domestic Supermarket; C-2: Charolais Export; C-3: Charolais Live Export; H-1: Hereford Supermarket; H-2: Hereford Grass Fed Steer; H-3: Hereford Grain Fed Steer; H-4: Hereford EU; SG-1: Santa Gertrudis Domestic Production; SG-2: Santa Gertrudis Export Production.

Differences shown do not imply similar differences in the average merit of breeds.

Figure 4. The inter-relation of stocking rate, genetic improvement, and $ per ha (schematic