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Australian Journal of Experimental Agriculture, 2006, **46**, 183–198

Breeding strategies for the development of the Australian beef industry: an overview

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Abstract. Strategic directions for the period 2010 to 2020 and research and development needs are considered for the Australian Beef Industry from the breeding sector's perspective. These are related to the way major technologies are developed for an industry, the current status and likely trends in market development and appropriation of benefits to the consumer, processor, commercial beef producer and breeding sectors. The primary strategic needs identified are: (i) understand the functional biology for the major production environments (supply chain packages), (ii) accelerate the speed of genetic improvement for production environment breeding goals based on commercial sector profitability and the dissemination of superior genetic material to this sector, and (iii) retain and develop the Beef Cooperative Research Centre concept over the period. Tactics for realising each strategy are considered. Rigorously designed industry-level studies based on a genotype × environment interaction approach, involving all major production environments and breeds, have an important role to play, as do the serial development of measuring equipment and procedures for carcass quality and yield, body maintenance, disease management and maternal performance. Information and communication, molecular genetics and artificial insemination technologies, along with formal progeny testing and an extended BREEDPLAN system, will be increasingly used by the breeding as well as commercial industry sectors to more consistently meet particular market demands. Carefully executed progeny testing is a pragmatic and necessary breeding approach for the period, serving a number of important purposes. The beef industry as a whole will need to take more responsibility for its genetic improvement element by: managing the appropriation of benefits across sectors, developing an increasingly effective system of value-based marketing and, for each sector and production environment, a more appropriate program of capacity building. The industry could now usefully consider the further development of its activity to address these longer-term strategic needs.

Additional keywords: adaptive fitness, artificial insemination, Beef Cooperative Research Centre (CRC), breeding, BREEDOBJECT, BREEDPLAN, carcass quality and yield, cattle, extension, feed intake, genetic improvement, genotype × environment interaction (GEI), management groups, production systems, progeny testing, value-added marketing.

Introduction

Bindon and Jones (2001) listed about 30 major events that have influenced the development of beef markets for the Australian industry since the 1930s. About one-third of these events are technological in nature. Each of these key technological events relied on various prior events for its development, such as one or more seminal research contributions, disease outbreaks and temporary loss of promising markets, or particular public sector initiative. With increasing frequency over time, one or more sectors of the industry itself have become directly involved during the early development stage of a major technology. In this way, the Beef Cooperative Research Centre (CRC) developed out of a Federal Government policy initiative. The initiative was aimed at stimulating coordinated public institutional efforts and direct private sector financial and operational involvement in tackling areas and issues of major importance to Australia and its industries. The initiative was also vital to the realisation of significant outcomes for the nation and preparation for their uptake and commercialisation by industry. The Beef CRC was made possible through a range of direct commitments from the processing, seed-stock-producing and commercial beef-producing sectors of the industry, and from 6 public institutions. Direct contributions of staff, land, cattle, funding and operational support enabled this major development for the industry (Bindon 2001).

The design of the Beef CRC's research and development (R&D) program (Bindon 2001; Upton *et al*. 2001) relied upon the introduction of the seed-stock producing sector to another of the major technological events listed by Bindon and Jones, the National Beef Recording Scheme (NBRS) BREEDPLAN system (Graser *et al*. 2005). The development of the pivotal analytical element of BREEDPLAN had relied heavily on the existence of a performance-recording scheme being used by breeders, and its central database. Performance recording was initiated through the action of New South Wales (NSW) Agriculture; the development of NBRS was subsequently coordinated by the other state departments of agriculture, the Agricultural Business Research Institute (ABRI) and industry, with the state departments providing substantial extension resources to introduce and support the technology. NBRS is marketed by ABRI and provides both pedigree and performance recording services.

The development of BREEDPLAN (Graser and Hammond 1985) was also made possible by seminal research for the United States of American dairy industry by the late Professor Charles R. Henderson and its interpretation by Henderson (1973). The analytical algorithms of even the first version of BREEDPLAN required comparatively powerful computing. Extensive pre-release testing in association with industry included repeated analyses of data and extended working sessions with a broad panel of cattle breeders, each actively utilising NBRS. Uptake of BREEDPLAN and one of its early extensions, Group BREEDPLAN, was enabled by the use of another technology, artificial insemination (AI), by some NBRS members. AI was introduced to Australia in the late 1940s. AI was necessary for the across-herd design of the CRC's R&D program and will be important to the industry's further use and development of progeny testing. Group BREEDPLAN development was also greatly facilitated by the direct involvement of a number of breed associations with NBRS. These associations provided the deep pedigrees which so strengthened the genetic evaluation analyses and helped to generate breeder confidence in the BREEDPLAN system. Another important enhancement to the BREEDPLAN system, BREEDOBJECT (Barwick *et al.* 1992), was implemented fifty years after the seminal theory (Hazel 1943) was interpreted for the beef industry, and was properly integrated with an estimated breeding value (EBV) prediction system.

Most of the major technologies introduced to the beef industry to date have been associated with a longer-term R&D effort directed at advancing understanding of the technology and its impact, refining and extending its use, and supporting the necessary ongoing education and training concerned with this use and extended development. Successful uptake and further development of these technologies also relied on informed extension services by the state departments of agriculture. For example, the Animal Genetics and Breeding Unit (AGBU), a dedicated R&D team created by NSW Agriculture and the University of New England, designed the BREEDPLAN system and was subsequently commissioned to lead the system's ongoing development (Graser *et al.* 2005). Informed extension was considered so important for the successful industry uptake of this complex genetic prediction technology that extension expertise was provided to the AGBU by departments of agriculture to coordinate national field uptake and support of BREEDDPLAN, and feedback. Subsequently, some breed associations also contracted highly-experienced extension expertise to support technology uptake. Freer *et al.* (2003) describe in some detail the development, present status and immediate future needs of the industry for breeding technology extension.

While being mindful of the historical process of the uptake of major technologies, this paper briefly considers future longer-term strategic technological needs of the beef industry seed-stock-producing sector. The focus is the breeder perspective, although the direction of the main benefit flow from genetic gain requires that these needs must also be addressed by the commercial industry sectors and consumers. In considering the breeder perspective, the advanced analytical techniques which are being used in the BREEDPLAN system to help tackle these breeding needs are accepted without addressing here their further development. This is already being treated in detail by industry R&D and on a continuing basis in the literature.

Who benefits?

Strategic planning and action for the industry will endeavour to account for major technological development, as well as for the appropriation of potential benefits arising from new technologies. Benefits are likely to be partially recouped by the domestic consumer, while industry sectors will benefit by the technologies generating higher production, processing and marketing efficiencies, and contributing to the maintenance of the industry's competitive position, internationally and domestically.

The flow of benefits between and within industry sectors is important. If the industry is to maintain and advance the development of major technologies, adequate benefit must be appropriated to the sector(s) that invest directly in the development and application of these technologies. This is particularly important for breeding, where genetic expression occurs on an underlying scale, is mainly recouped by the commercial beef producer, processor and consumer sectors, and is intergenerational, compounding over time to provide potentially large benefits. Economic evaluations of return on investment in breeding and genetics R&D show very healthy outcomes for net present value, benefit:cost ratio and internal rate of return; for example, see the detailed evaluation for the southern Australian industry over 1970 to 2001 by Farquharson *et al.* (2003). Economic studies have not as yet established the benefit flow to each industry sector, but it is likely that appropriation of benefits to the industry's breeding sector is insufficient to cover the costs of generating rapid genetic improvement for the industry while remaining profitable. If so, the industry will need to devise and manage ongoing procedures which redress this issue of most of the benefit from genetic improvement being appropriated beyond the breeding sector, while it shoulders the vast majority of the investment in breeding.

Future directions

Breeding addresses the industry's future directions and needs—it is done for tomorrow! Longer-term strategic planning and action is essential then for the industry to realise early the substantial potential benefits of rapid generation and wide dissemination of genetic improvement.

Demand for specification and increasing market segmentation of meat is advancing internationally. Fundamentally, these are being driven by the recent rapid developments in the applied information and communications technologies, and subsequently by increasing consumer awareness of product quality and of biosecurity and sustainability issues, assisted along by the broad range of ways beef is prepared in local cuisine. The demand changes are occurring rapidly, in years rather than generations. Diverse product specifications offer some flexibility to decision-makers at each link in the production–processing–marketing chain. Over time, segment specifications may further narrow. The emphasis on product consistency will increase and, despite some likely intermediate-term increase in international demand for Australian beef from possible World Trade Organization and European Commission Common Agricultural Policy changes, we should anticipate continuing decline in the longer-term terms-of-trade for beef. Collectively, these changes in the market will drive the progressive development of integrated supply chain packages (production environments), each customised throughout to address one or a small number of mutually supporting market segments. In the context of broad industry genetic improvement, a supply chain package is a production environment, encompassing elements of all industry sectors, breeding through to consumption, because genetic variability for traits of importance will variously impact productivity and product quality, and therefore competitiveness and profitability throughout the chain.

The Australian industry will, therefore, further segment into a small number of diverse production environments, each customised throughout the breeding–production–processing chain to supply more consistently specific market segments. 'Production' is used here to encompass weaner production, backgrounding and finishing. Realising particular product and production specifications and retaining competitive advantage, while maintaining reasonable profit margins will remain challenging for each production environment. It will increasingly demand clear understanding and sound management of all variables operating at each link in the supply chain. This is a major challenge for Australian beef. As production is biologically complex and production will continue to be exposed to climatic vagaries, our understanding of how best to manage production is still quite immature. Improvements will be increasingly technology driven, requiring keen familiarity by decision-makers throughout each supply chain with how to best utilise an expanding range of advancing technologies. Major strategic R&D activity will continue to be required to help the industry to meet this challenge. The further partitioning of the industry into supply chain packages should, in addition to facilitating technology uptake and use, provide feedback to help clarify beef improvement and technological development needs. The supply chain package must increasingly serve to crystallise understanding of the specific requirements to be met by each sector and segment of the production environment, while the effective use of technologies invoked in a supply chain package will require highly informed management at each point. It is obvious that training and field technical support will also become increasingly important for industry success.

The Beef CRC was established to focus effort on strategic R&D. 'Strategic' addresses the questions: Where are we now? Where do we want to be in future? What do we need to do to get to where we want to be? The CRC has targeted the most sensitive supply chain links involved in the production, processing and marketing of least-cost, designer beef. The work required major effort. The CRC marshaled the human and financial resources required to realise significant advances and industry impact from many institutions and a broad range of disciplinary areas (Bindon 2001). A highly integrated, multidisciplinary R&D program was introduced, incorporating a strong education and extension arm (Bindon 2001; Bindon *et al.* 2001). To have national impact, the program also needed to take account of the existing broad range of primary beef production environments and genetic types used by the industry to produce beef in Australia, as well as a number of important technological trends in production, processing and marketing (Bindon 2001). The CRC R&D program initiated a large cattle-breeding program, the design of which enabled the integrated study of the genetic and non-genetic elements of producing quality beef.

This approach by the Beef CRC may also offer the industry a cost-effective platform for use in filling the major strategic technological needs of each supply chain. Fundamental questions concerning this opportunity for the industry then are: (i) what are likely to be important longer-term strategic needs and issues? and (ii) how should the beef industry position itself to maintain such highly integrated and substantial but flexible R&D infrastructure?

Strategic needs

What strategic technological developments are required for the industry to keep pace with the competition, from a breeding perspective? Let us consider the period 2010 to 2020. This is beyond that period, 2004 to 2009, for which the Red Meat Advisory Council has recently completed an overall strategic plan for the industry (RMAC 2003), which is now being addressed (MLA 2004). The period between 2010 and 2020 may seem distant, but the R&D required to achieve a major technology always takes time and broad-scale uptake of results often takes more time again. The lead-up R&D should already have commenced for the industry to realise the widespread uptake of a technological development during this period. During this period, reduction in soil moisture and increasing variability of climate throughout Australia (Intergovernmental Panel on Climate Change 2005) is likely to impact the economics of beef production, resulting in added economic pressure and some redistribution of the herd, particularly in the more vulnerable south.

Three major strategic targets are particularly important to help the Australian beef industry maintain its competitive position and profitability throughout 2010 to 2020. These are:

(1) obtain a much better understanding of beef production functional biology for the major Australian production environments [The term 'functional biology' is used rather than physiology to better encompass all elements of function in the biological systems involved.] ;
(2) Accelerate the speed of genetic improvement and the dissemination of these gains, for the breeding goal established for each of the important production environments of the industry;
(3) retain the Beef CRC infrastructure and operation at least at its existing capacity.

Some important elements of each of these 3 mutually dependent strategies are now considered.

1. Understanding the functional biology for the major beef production environments

R&D on this strategy commenced decades ago. Progress was rather slow and inefficient until the Beef CRC was formed. In addition to the CRC mustering the required breadth and depth of expertise, institutional involvement and resources to address the strategy, the CRC's timing was important to its early success. A number of informatics (measuring, computing, communications and analytical) and molecular (genetic, developmental, immunological, metabolic) tools had become available which are critical to rapidly- and cost-effectively-progressing work on this strategy.

The R&D required to address the strategy will involve at least several decades of work. Along the way, important outcomes for industry use will be generated. Major outcomes should enable:

(i) Industry specification and development of those production systems capable of consistently, efficiently and sustainably supplying the major market segments.
(ii) Development of increasingly lower-cost, rapid, reliable and timely measurement techniques for the important carcass quality and yield traits, body maintenance and health management. The carcass measurements must possess utility throughout the supply chain in the breeding, commercial beef producing, processing and marketing sectors.
(iii) Development and industry-wide use of a value-based marketing system which enables adequate appropriation of the benefits of genetic improvement to drive the breeding sector to invest in acheiving the required gains (Parnell 2004). Even if vertical integration were to develop in the industry to supply particular market segments, the diversity of segments and of the production systems is likely eventually to favour genuine value-based marketing. For improvement to be maximised, the clarity and integrity of feedback throughout each supply chain is essential. The introduction of the Meat Standards Australia (MSA) grading system was an important step in industry development, as shown by the resulting increase in consumer confidence, as reported by Meat and Livestock Australia (2002). To successfully address strategies for breeding, the MSA grading system should be developed and combined with automated yield measurement to realise an effective system of value-based marketing for use by all sectors. Polkinghorne *et al*. (2006) developed novel carcass breakdown, fabrication and software systems to demonstrate the feasibility of such 'truly transparent' value-based marketing. They consider that the consumer focus delivered by MSA could be applied commercially across all sectors.
(iv) Development of a coordinated education program for all sectors of each beef supply chain, such that the values of genetic and non-genetic factors are clearly understood. This understanding by all sectors of the beef supply chain will be critical to achieving the outcomes described in points (i), (ii), and (iii) above. For example, effective value-based marketing will only become a reality when the processor realises that there are genetic differences for carcass traits and that the breeder controls the genetics. To achieve the benefits of genetic improvement the processor must be prepared to appropriate some of this benefit back along the chain.

In a genetic context, clear understanding of the requirements for developing each of the industry's diverse production environments requires industry-level characterisation within and between these environments. To realise the strategy, genotype × environment interactions (GEIs) must be central to the design of all major R&D activity.

Genotype × environment interaction

Globally, over time GEIs have been extensively studied at the quantitative genetic breed and animal levels in most domestic animal species, for a comparatively small number of breeds, traits and particular environments. A summary overview of the substantial research follows. For some traits, breeds and environments, there were marked differences in ranking of the genotypes between environments studied, these rank changes being larger the more diverse the environments and genotypes considered. For other traits there were changes in relative position of the genotypes between environments, without changes of rank. With a few traits, environments and studies no GEIs were detected. The more thoroughly traits were examined, the greater the likelihood of GEI detection. This outcome is not at all surprising given that phenotypes are the end product of genetic constitution and total environment experience.

Cundiff (1989) gave two broad reasons for needing to understand GEIs: to establish appropriate analytical procedures for genetic evaluation across and within breeds, and to match genetic potential with the climate, feed resources and market opportunities during breeding. To properly address both areas requires that quantitative genetic studies be conducted jointly with comprehensive studies directed at understanding the functional biology of the production systems involved. Beef production GEI studies though have tended to focus only on quantitative genetic analysis. Of course there were reasons for this approach. Production of beef is biologically complex and dependent on the environment, and the tools for doing R&D directed at understanding functional biology have until very recently been relatively crude. It was much simpler and far less costly and time consuming for those interested in GEIs to fit statistical models including GEI terms to existing performance recorded data. This has been a common and frequently a further serious constraint of GEI work, where the efficiency of alternate experimental designs can vary greatly (e.g. Solkner and James 1990).

The required R&D must be based upon large-scale, detailed field trials for the industry to achieve the most cost-effective, rapid and sustainable improvement in the genetic and non-genetic factors that influence efficiency and consistency of quality beef production for each market segment. Designed and conducted well, this work could now be performed as a once-off study, which would provide information for decades. Its basic design provisions must enable subsequent, reliable incorporation into the research program results, studies of new methods, procedures, and the inputs and output demanded. The basic design must incorporate the industry's important production environments, the breeds being used and considered for production, together with particular crosses of these, and the traits of importance. An account is required of all input and output quantity and quality traits of importance to profitable beef production in each environment. It is imperative that these studies incorporate the functional levels of animals and inputs to them such as production of feeds. Properly achieving these requirements in the past was generally prohibitive. Now, with current biological, statistical and other informatic technologies, and careful integration of resources, this industry-level activity should be feasible, although still challenging. Some staging would be possible but will increase substantially overall cost and timing of results. Design 'short-cuts' impose potentially serious deficiencies for matching genetic potential with non-genetic inputs and market opportunities through neglect of some important breeds, environments and traits. Short-cuts generate the need for costly, time-consuming repeat R&D, constraining the industry's ability to further develop competitive and profitable supply chain packages within available time horizons.

The design and operational approach to these industry-level studies of the functional biology of beef production should directly assist the industry to maintain its competitive position and profit while minimising its costs. The results should provide the necessary information for use in the many breeding and commercial beef producing sector decisions concerned with how to generate increased genetic gains via improved sampling, selection and mating strategies, between, as well as within, breeds and crosses. Of course, lack of this information should not delay the establishment of breeding goals and execution of designed breeding programs; these can be progressively upgraded as results develop. The results should directly contribute to a broad range of strategic decision-making in the non-genetic biological and economic aspects of commercial production and processing. The R&D and its outcome would serve to closely and properly integrate the range of genetic and non-genetic R&D required to meet the industry's needs. In addition to assisting all industry sectors to further develop the current breeds and production environments, and respond to market opportunities, this R&D would also contribute valuable information to help the industry respond cost-effectively to future change.

The Beef CRC phases I and II have begun to address this major strategic challenge (Bindon 2001). The second phase CRC work is focused in the commercial sector (McKiernan *et al*. 2005), the major contributor to short-term industry profitability and competitiveness. Notter (1991) considered that GEI may be more important in commercial beef production than in seed-stock herds. However, executing suitably rigorous experimental designs and generating adequate genetic information in this sector remains challenging.

It may be argued that understanding the functional biology of beef production by market segment and customising production systems to suit them is of little benefit, as consumer demand and, consequently, product specification changes over time. While these system changes are important, they generally are second order. Advanced understanding of the functional biology and quantitative genetics of the production environments will enable rapid accommodation in established production systems of such second order developments.

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