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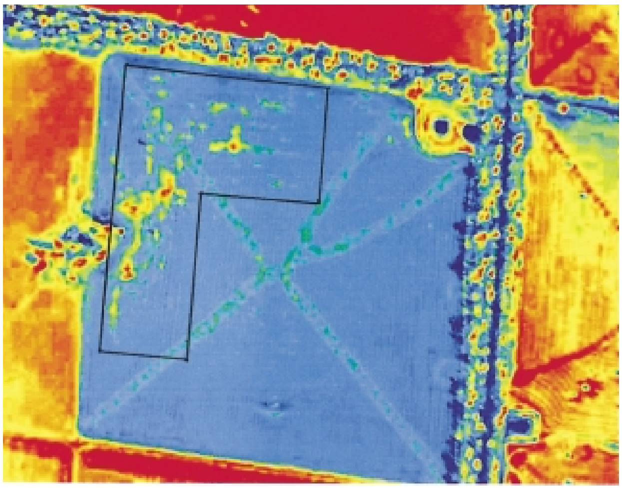

Volume 41, 2001

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Australian Journal of Experimental Agriculture, 2001, **41**, 1073–1087

Communication, education and training strategies to deliver CRC outcomes to beef industry stakeholders

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Abstract. At the commencement of the Cooperative Research Centre for the Cattle and Beef Industry (Meat Quality) participating scientists were encouraged to anticipate the methods and channels that might be used to deliver the Cooperative Research Centre's research outcomes to beef industry end-users. This important step was seen as the completion of the process, which began with the beef industry issue, leading then to formulation of the Cooperative Research Centre concept, initiation of the research program, completion of research and finally commercialisation or delivery of products and processes to industry. This paper deals with techniques, institutions and commercial arrangements employed to achieve delivery and adoption of diverse outcomes of the Cooperative Research Centre.

Introduction

A feature of Australia's Cooperative Research Centre's (CRC) program has been a requirement to plan effective technology-transfer strategies to ensure that research results are adopted by industry end-users in the shortest possible time. A deficiency in this area has been recognised as a failure of industrial research in Australia for many years (Dart *et al.* 1998). The Australian Government's view was re-stated by the (then) Minister for Industry, Science and Tourism, John Moore (1998). In announcing expansion of the CRCs program, he commented:

"(The CRC's program)…has developed a new paradigm for cooperation between researchers, and research users in both the private and public sector. These strategic links between researchers and users provide industry with access to a collaborative research environment not previously available. We are starting to see a better appreciation by industry of the benefits of these strategic arrangements, rather than relying solely on short-term research projects to address immediate problems. Industry participants are directly involved in the planning and management of the research program within CRCs… Achieving commercial and other outcomes from the program requires an effective process of technology transfer to industry and other users. I wish to see a strong focus on technology transfer mechanisms, including education and training programs, industry extension activities, and other means."

The goal of the CRC for the Cattle and Beef Industry (Meat Quality) from the outset was to improve the domestic and international competitiveness of the Australian beef industry. Success in achieving this goal depended very much on taking research outputs and turning these into industry outcomes by effective delivery to end-users. Extension practitioners identify 4 major strategies or models in agricultural extension (Black 2000), which include: (i) linear 'top-down' transfer of technology; (ii) participatory 'bottom-up' approaches; (iii) one-to-one advice or information exchange; and (iv) formal or structured education and training.

The general consensus is that no single model or strategy is likely to be effective in achieving adoption of agricultural research outcomes (Black 2000). Hence, the CRC for the Cattle and Beef Industry (Meat Quality) chose to use all of these strategies to varying degrees to target particular beef industry stakeholders and for different technologies such as genetic information, genetic markers, management tools and techniques and products such as vaccines developed by the CRC. This paper describes the different approaches taken by the CRC to achieve delivery of outcomes to beef industry stakeholders, attempts to evaluate the effectiveness of the different methods, and makes recommendations on possible new approaches to further improve delivery of outcomes to beef industry stakeholders.

Strategies for utilisation and application of research outputs

Figure 1 illustrates the CRC's strategies for delivery of CRC products and processes through commercialisation (marketing) and 'public domain' pathways. Examples of CRC outputs that have been handled through these pathways are dealt with in this paper.

Stakeholders of the CRC include all sectors of the beef industry supply chain, meat processors and exporters as well

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as beef consumers in the community. They also include students, other scientists, sponsors, agribusiness firms, funding agencies and politicians. Figure 2 outlines the different forms of communication that the CRC utilises to ensure research results are made available to the different stakeholder groups. Effective communication to all these groups is a demanding and continuous process.

Underpinning initial development of the CRC's research and development program, participatory approaches were used to identify the highest priority researchable issues. The participatory approach was extended through direct involvement of end-users in the CRC's research program, including the experimental design of the CRC's core breeding programs and the generation of pedigreed experimental cattle described by Upton *et al.* (2001). Traditional technology transfer approaches are used for many of the communications shown in Figure 2 (annual reports, sponsor's reports, specialised newsletters aimed at external technology transfer agents and consultants, field days and seminars). Participatory and one-to-one advice or information transfer particularly applies to CRC sponsors, who are entitled to exclusive advance access to CRC results in return for their sponsorship of the CRC. These latter activities tend to be by way of property visits or local group meetings, to directly address issues relating to implementation of CRC outcomes by the sponsors. Structured education and training courses are also delivered to key stakeholders as indicated in Figure 2.

Genetic improvement technologies

Genetic outcomes from CRC research include both quantitative and molecular genetic information. The CRC's approach to deliver these outcomes varies to accommodate the different level of technical and commercial expertise required for early adoption of the different technologies.

Quantitative genetic outcomes

The CRC has completed the world's most complex (number of genotypes and number of recorded traits) progeny test for carcass and beef quality traits and efficiency of feed utilisation. It includes the following refinements: link sires across all herds, within a breed; standard slaughter protocol for all cattle; scientific allocation of progeny to treatments; full range of meat quality traits, including tenderness; progeny allocated within sire, to 3 representative market (slaughter weights) end-points. Genetic outcomes include heritabilities of these new traits and their genetic relationships with other traits that are already being used in

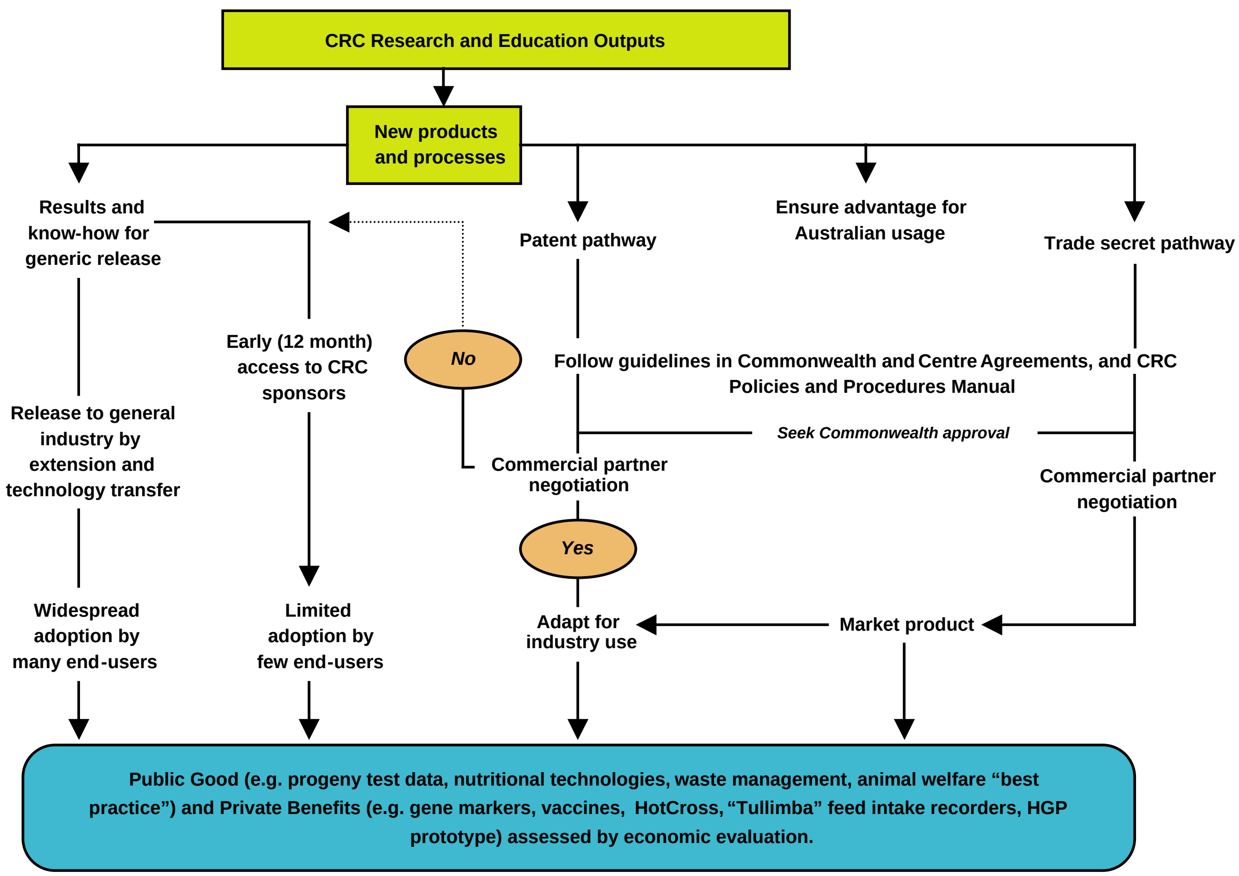

Figure 1. The generic pathways to be used to maximise adoption and utilisation of CRC research.

designed breeding programs. A second tier of genetic information relates to quantification of the magnitude of genotype × environment interactions resulting from systematic comparison of sire progeny groups in different geographical locations (e.g. Central Queensland *v.* northern NSW) or in contrasting nutritional finishing regimes (e.g. pasture- *v.* grain-finishing). The CRC's comprehensive experimental design also provided for comparison of sire progeny groups at different market endpoints (domestic *v.* Korean *v.* Japanese markets). A third tier of information relates to Estimated Breeding Values (EBVs) for the many sires and range of traits covered by the CRC's experimental design. Each of these genetic outcomes requires specialised but different delivery mechanisms to ensure adoption of the information.

In delivering these technologies to the seedstock and commercial beef cattle breeding sectors, the CRC anticipated the integration of new genetic information opportunities, as shown in Figure 3.

BREEDPLAN

BREEDPLAN is the ultimate delivery vehicle of all of the CRC's genetic technologies. BREEDPLAN is Australia's national beef genetic evaluation scheme administered by the Agricultural and Business Research Institute (ABRI), Armidale. In recent years, the scheme has also expanded rapidly to include international evaluation, either for individual breeders from overseas or as part of a breed society international genetic evaluation. The scheme was used as the major delivery vehicle for all of the CRC's growth, carcass and meat quality genetic outcomes. CRC data were used to underpin development of new genetic evaluations for the 7 cattle breeds involved with the CRC, specifically for new traits such as retail beef yield and marbling derived from carcass data. The newly released BREEDPLAN Version 4.1 (Johnston *et al.* 1999) provided the world's first national EBVs for carcass attributes and is a direct result of use of CRC data. BREEDPLAN Version 4.1 could not have been achieved without the use of CRC data.

While some of the genetic technologies developed by the CRC are relatively simple to integrate into national genetic improvement schemes (e.g. new genetic parameters), others require considerable cooperation between commercial partners. For example, new selection criteria can require special standards of recording and licensing of recorders (for example, ultrasound scanning; Upton *et al.* 1999). Proficiency testing of ultrasound scanning operators has led to confidence in the measurement technique and rapid adoption of the technology for genetic evaluation.

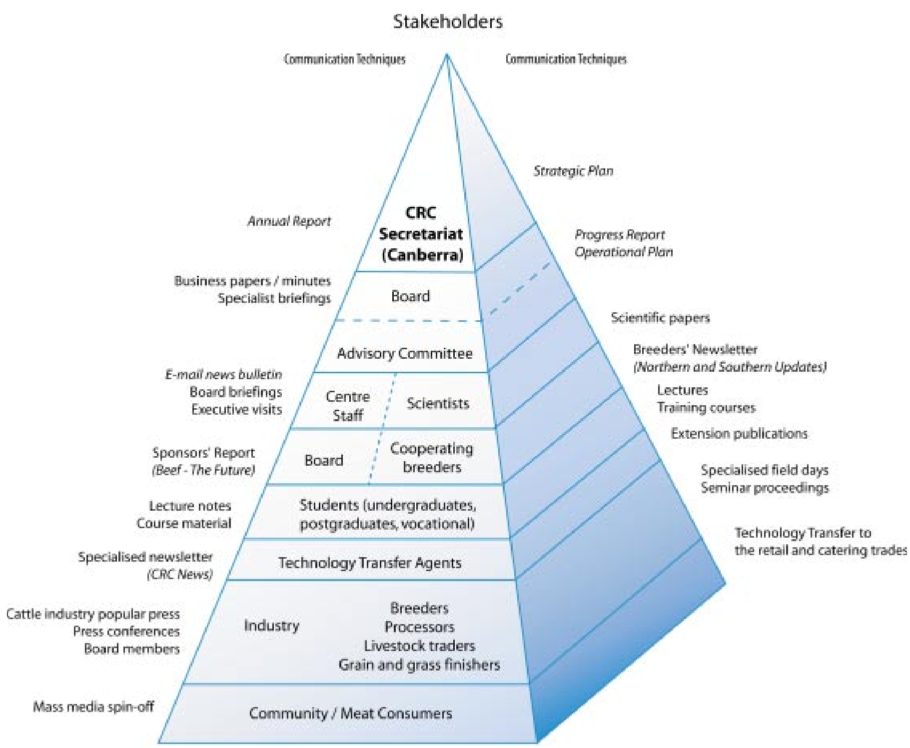

Figure 2. Examples of different communication techniques used by the CRC for the Cattle and Beef Industry (Meat Quality) to specifically target different beef industry stakeholders. The diagram represents the cascade of information flow to hierarchical priority end-user groups. Vertical axis also reflects the size of stakeholder groups.

As a direct result of the CRC's comprehensive progeny-testing program, outstanding genetic lines have been identified in several breeds for vitally important traits such as carcass yield, marbling, beef tenderness and feed efficiency. These EBVs have allowed seedstock breeders to genetically improve their own herds and also genetically improve their clients' herds, through greater accuracy in targeting genetics for specific meat markets.

Breed Object

Breed Object is a selection tool to help breed more profitable cattle (Barwick and Yeates 1997) and is used in conjunction with BREEDPLAN (Barwick *et al.* 1992, 1994; Schneeberger *et al.* 1992). It is a PC software package that helps with selection by combining all the EBV performance figures on an animal into a single EBV for profit (the $Index, an EBV for profit in the commercial herd) which describes how well the animal suits the user's purpose. It targets the specific purpose defined by the breeder and can be used by both stud and commercial cattle breeders, or potentially, anyone in the cattle production chain with an interest in selecting cattle. Examples are available of Breed Object usage by bull breeders, bull buyers, breed societies, semen companies and others. Opportunities for service providers are numerous, but payoffs depend on the capacity of users to capture sufficient of the benefits accruing from genetic improvement and the better identification of superior sires.

CRC genetic outcomes have been used to refine Breed Object, through the introduction of new carcass and beef quality attributes and efficiency of feed utilisation that have allowed estimation of relative economic values for these traits (Barwick and Henzell 1999; Barwick *et al.* 1999). Estimation of relative economic values for intramuscular fat percentage (marbling), retail beef yield percentage, fat depth and eye muscle area all on a 300 kg steer carcass basis provides beef producers with a calculated assessment of risk of using the new EBVs. It also provides guidelines on the economic feasibility of incorporating new measurements into selection criteria for seedstock herds. By way of example, the revised Breed Object package was used to investigate 2 separate scenarios in order to make direct recommendations to seedstock breeders. The scenarios were the following:

(i) The effects of recording new measures of intramuscular fat percentage (IMF%), mature cow weight and net feed intake (NFI) on selection was examined (Barwick *et al.* 1999). NFI is defined in Robinson and Oddy (2001) and it is actual feed intake adjusted for liveweight and current growth rate. Recording IMF% increased the accuracy of selection by more than 30% for an objective that targeted production for the high quality Japanese market. Recording NFI increased selection accuracy by up to a further 42% for the Japanese objective and 14% for an objective that targeted the domestic market.

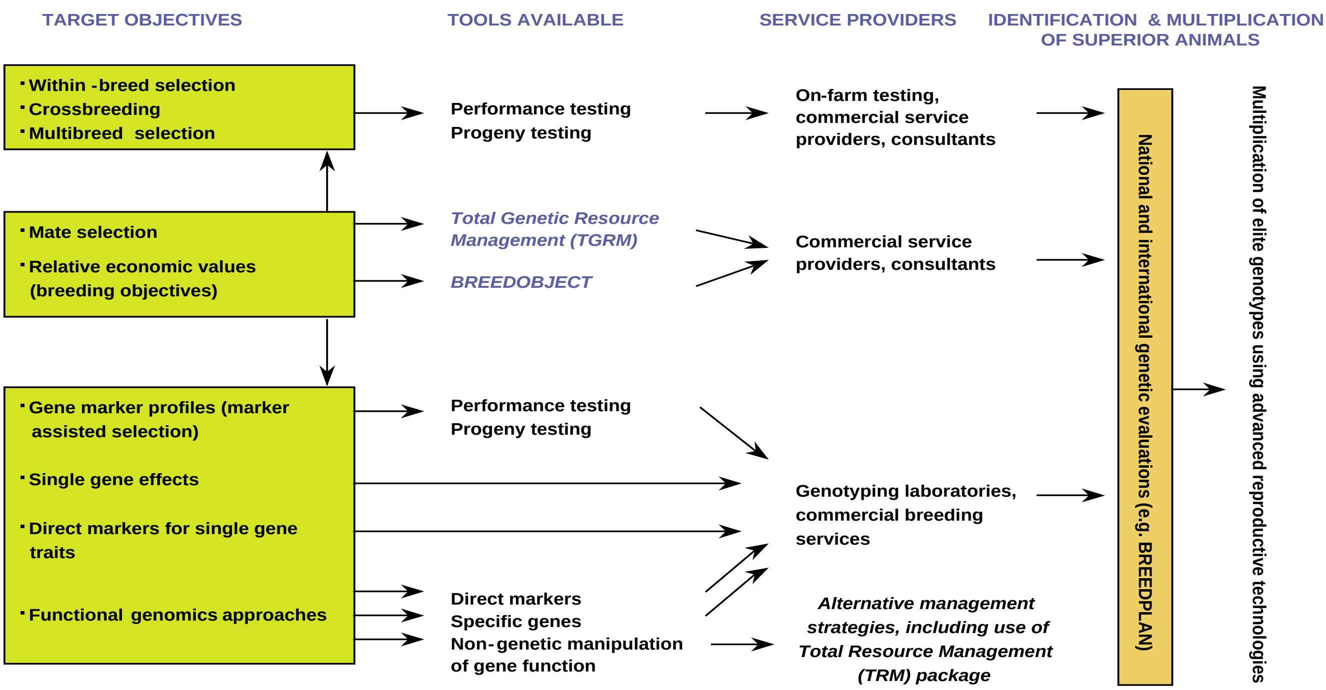

Figure 3. Technologies available to fast-track genetic improvement of Australian beef cattle.

(ii) The benefits of recording NFI in industry breeding schemes was investigated using a model of investment and gene flow resulting from selection activities (Archer and Barwick 1999). The results showed that where the breeding objective targeted the high quality Japanese market, it was profitable to record NFI on all bulls in the seedstock sector where NFI measurement costs were as high as A$450/bull. Where the breeding objective targeted a domestic grass-fed market, recording NFI on all bulls was only marginally profitable when measurement costs were A$150/bull and was not profitable at higher measurement costs.

Results of modelling exercises such as those outlined above have been widely distributed particularly to CRC sponsors. They have also been used to target potential users of the new selection criteria in more recent times, through establishment of a web site that allows potential users to use the Breed Object package to assess animals for use in their own herds (http://www.breedobject.com/).

Molecular genetic technologies

The CRC's molecular genetics research began in 1992, with specially designed 'gene marker families' of Charolais × Brahman cattle that were genotyped against a range of genetic probes then matched to carcass and beef quality phenotypes. Statistical analyses subsequently highlighted significant associations between particular chromosomal regions and specific beef quality attributes. The associations were further evaluated in the CRC's progeny test data in 7 beef cattle breeds. Results of this research were reported by Hetzel *et al.* (1997) and Hetzel and Davis (1999) and are summarised in Burrow *et al.* (2001). The CRC's molecular genetics outcomes have now been submitted to a commercialisation process shown in Figure 4, with 3 separate approaches being taken. These approaches include: (i) establishment of a commercial company marketing a series of direct and indirect gene marker tests to cattle breeders; (ii) development of marker assisted selection (MAS) protocols to assist breeders wishing to become involved in MAS; and (iii) initiation of a development project by one of the CRC's commercial sponsors using a Federal Government START grant. All methods involve a commercial partner (Genetic Solutions Pty Ltd) an independent Australian company formed as a spin-off company by the CRC scientists initially responsible for the research.

Direct and indirect gene marker tests for carcass and beef quality attributes

To directly market DNA-based gene marker technologies in a practical form, Genetic Solutions Pty Ltd created a subsidiary company called GeneSTAR Pty Ltd. GeneSTAR Pty Ltd will bring to the Australian and international beef industries direct and linked genetic markers that have utility in a range of production systems and environments. The focus will be on genetic improvement technologies for traits that are difficult to measure or breed for. 'GeneSTAR Marbling', a direct marker that distinguishes between alleles of the *Thyroglobulin* gene, is the lead product for the company, being the first gene marker for a production trait in beef cattle anywhere in the world. The product is a DNA diagnostic test for a major gene associated with marbling and the test enables cattle breeders to select individuals that carry 1 or 2 copies of the favourable allele. Marketing of this and other currently available tests (e.g. DNA fingerprinting) and new tests as they are released to the commercial company by the CRC and its consortium partners are or will be available directly on-line (http://www.genestar.com.au/).

Marker-assisted selection

Research is continuing in the new CRC for Cattle and Beef Quality to further validate promising genetic markers and candidate genes or to develop new markers for the same and new traits. As well, development of methods to incorporate markers into designed breeding programs is continuing. However, as an example of implementation of marker information in established breeding programs, Davis and Hetzel (1999) describe how an enhanced progeny test can be developed for sires that will allow a Gene Marker Profile to be developed for carcass and beef quality attributes (Fig. 5). The Gene Marker Profile they propose can thereafter be used for selection amongst progeny and grandprogeny without the need for further progeny testing. In such a system, key sires are mated with commercial cows first to produce progeny for slaughter and to develop the Gene Marker Profile. In the following year, they are mated to stud cows to produce bull and heifer seedstock progeny. These seedstock progeny would then be available for selection with Gene Marker Profile information. They could thus be selected for genetic merit for carcass and beef quality attributes without the need for progeny testing.

The increasing level of sophistication and specification in the Australian beef industry is being driven by increasing demands of both the premium export and domestic markets. These specifications are largely in terms of carcass characteristics and meat quality attributes and are the main price determinants for product targeted to high-value domestic and export markets. However, virtually all of these traits are difficult to measure in the live animal, particularly in animals that are being used for animal improvement. The need for progeny testing to provide accurate estimates of breeding values of these traits is seen as a significant impediment to their improvement.

There are currently about 11 million breeding cows in beef herds in Australia requiring about 100 000 new bulls for mating annually. About 40% of these sires are derived from herds where modern genetic improvement technology is utilised. The structure of the industry and the nature of genetic improvement mean that even if only a limited number of breeders utilise a particular technology, the benefits are distributed to the rest of the industry through the sale of genetics in the form of semen, embryos, bulls or heifers.

Hetzel and Davis (1997) suggest that gene markers will be used to predict the breeding value of an animal for any particular trait (Fig. 4). The accuracy of prediction will vary and gene markers will generally be used in combination with information on relatives. In this context, gene markers can be considered an additional technology that can help breeders achieve a particular breeding goal. Other breeding tools currently available include artificial insemination and embryo transfer as well as genetic evaluation packages such as BREEDPLAN. Hetzel and Davis (1997) suggested that breeders will access gene marker technology in the following 3 ways:

(i) Buy breeding stock bred using gene markers. This is the simplest option and will be the most attractive for commercial breeders and small seedstock breeders. In this case, the breeder will not use gene markers directly, but will benefit by using superior breeding stock. Such breeders should expect to pay a premium for the superior stock, given that commercial stock of higher value will be produced.

(ii) Within-herd evaluation of gene markers and ongoing selection using gene marker profiles. The best use of gene markers will be achieved by, first, evaluating them within a breeder's herd (Fig. 5). In this way, the best gene markers can be selected for ongoing use and the gene marker effects will be estimated in the relevant genetic background. Given the likelihood that optimum gene marker profiles will vary between family lines, there is a need to evaluate each sire line. Through progeny testing, gene marker profiles are established for each sire line but thereafter, ongoing evaluation of gene markers is not required (i.e. subsequent offspring can be ranked on their breeding values calculated from their profiles and any other performance information). Where linked, rather than direct, markers are used, breeders will need to re-evaluate the gene markers from time to time.

(iii) Buy breeding stock with gene marker profiles and select offspring using the gene markers. Given the significant cost and effort required to comprehensively evaluate linked gene markers, it is likely that only some breeders will choose option (ii). A further option is for breeders to purchase bulls and cows with established gene marker profiles and to use the gene markers in their ongoing breeding program. This option will save on the cost of evaluating gene markers. However, its effectiveness will rely on being able to buy breeding stock with comprehensive gene marker profiles relevant to the breeding goals of the purchaser.

Development project initiated by a collaborating Northern Pastoral Company

The third approach to utilisation of genetic marker information in industry breeding programs is that taken by a

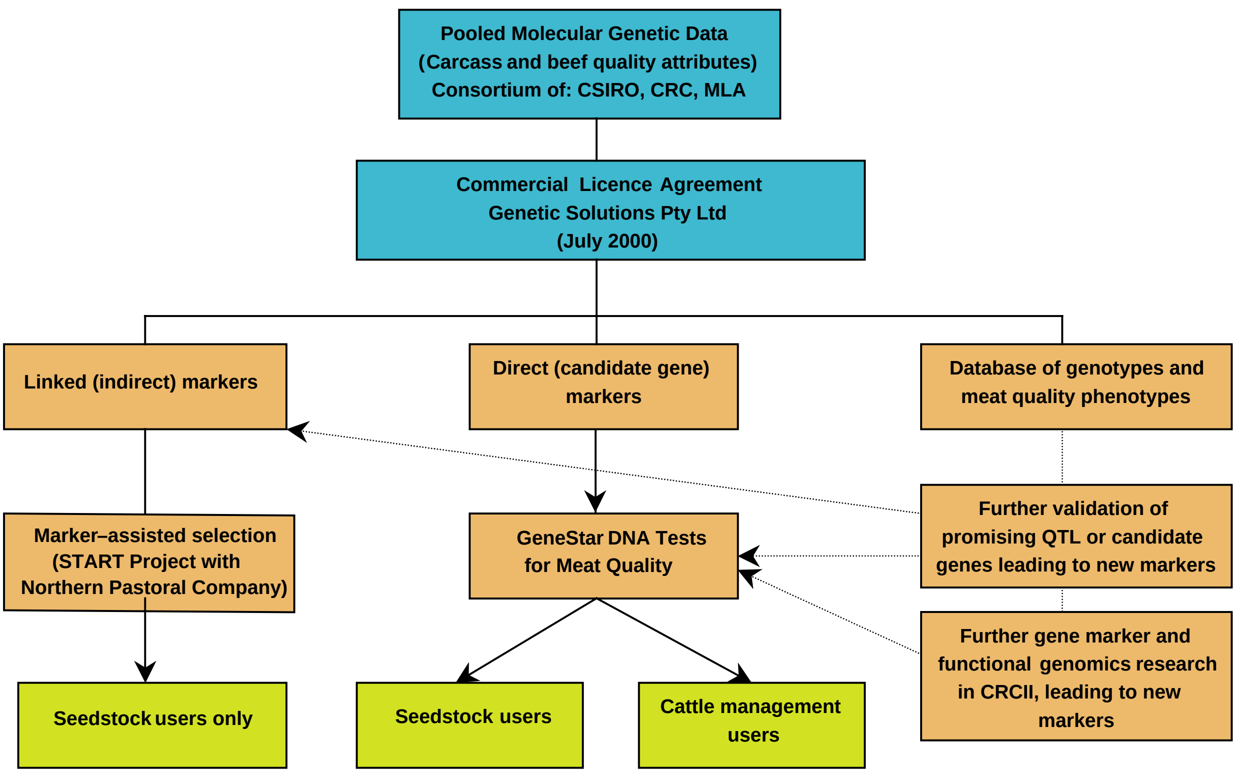

Figure 4. Gene marker technology development and utilisation for cattle genetic improvement.

major northern pastoral company (NAPCO), in conjunction with Genetic Solutions Pty Ltd, CSIRO and the CRC, based on funding from a START grant from the Australian Department of Industry, Science and Resources. The project, titled: 'Development of gene marker profiles for genetic improvement in the production and quality of Australian export beef cattle', involves identification of ways industry can adopt gene marker technology at the commercial level in a project. The aim of the project is to develop existing gene marker technology to make it commercially applicable to the northern beef industry. As part of ongoing CRC research in the new CRC for Cattle and Beef Quality, genetic linkages have been generated with experimental animals in the START project to enhance identification and validation of existing and new gene markers for hard-to-measure traits.

Total genetic resource management (*TGRM*)

Total genetic resource management (TGRM) is a computer-based breeding aid that is largely driven by specifying desired outcomes of a breeding program (Kinghorn and Shepherd 1999). Desired outcomes can be expressed in terms of genetic gains, exploitation of heterosis, maintenance of genetic diversity, operational costs, logistical constraints to be satisfied or other criteria nominated by the breeder.

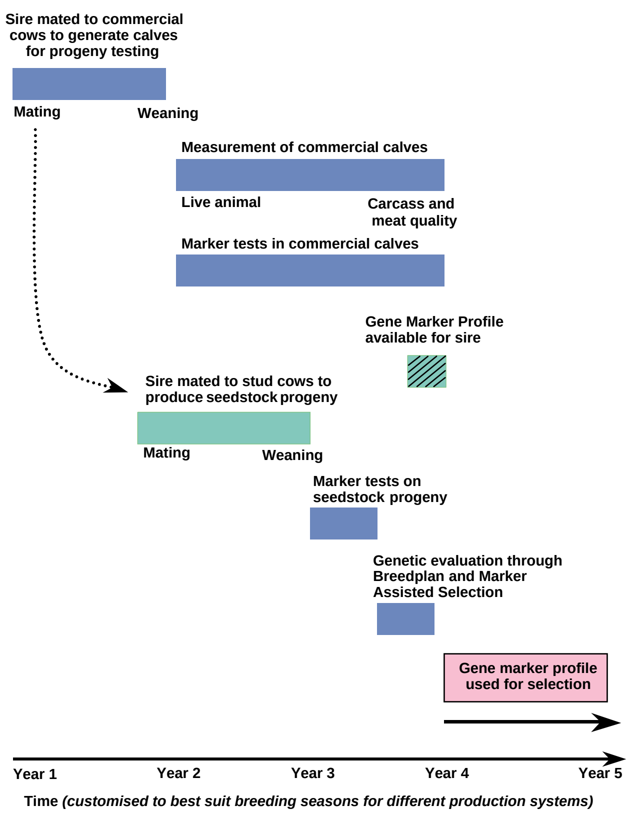

Figure 5. Timing for development of a Gene Marker Profile for a sire and for its use in selection of progeny in a marker-assisted selection program (from Davis and Hetzel 1999).

TGRM works tactically, meaning that it makes on-the-ground decisions at the level of existing animals, using current EBVs from a service such as BREEDPLAN, operational constraints and prices. Hence, the key output from TGRM is a mating list, which dictates issues such as semen collection and purchase and animal migration, as well as selections and matings. This is quite different from breeding aids that provide information, typically on trait EBVs, and then leave decisions on implementation to the breeders.

In any breeding operation, there is an almost infinite range of actions that can be made, involving decisions on issues such as animal selection, semen collection and purchase, and mate allocations. Each set of actions is predicted to have a given utility to the breeder, based on factors such as genetic gains, risk, costs and constraints satisfied. TGRM works by searching across all these possible routes ahead, and finding the one that is predicted to best suit the breeder's needs. This has only recently become possible because of development of efficient computing algorithms that mimic evolutionary processes to find appropriate solutions.

TGRM has been available to animal breeders on an individual consultancy basis (http://tgrm.une.edu.au/), with options for much wider commercialisation of the service currently being considered. The TGRM service, which is accessed by operators via the Internet, was initially used in the Australian lamb industry, where it is delivering significant increases in rates of genetic gain in a range of sheep breeds and is helping breeders solve a number of design problems simply and quickly (Banks *et al.* 1999).

Non-genetic outcomes of CRC Research

Total resource management (*TRM*)

A tool conceived during CRC I and under development by the new CRC for Cattle and Beef Quality is another computer-based package called total resource management (TRM; Kinghorn 1999). TRM will extend the TGRM package to make tactical optimisation decisions in the production and processing sectors, as implied in Figure 6.

TRM is aimed at accommodating factors such as: (i) setting mating dates to synchronise availability of young stock with the production system needs; (ii) opportunities to draft separate management groups at different ages and weight ranges, constrained by paddocks and labour; (iii) levels of feeding, stocking rates, and management within groups; (iv) time and space scheduling of limited facilities such as feedlot spaces; (v) predicted optimal pathways from any one point in the chain, through to different product end-points; and (vi) targeted outcomes to satisfy product objectives, cost constraints, prevailing pricing systems and contracts undertaken.

TRM will be of most benefit in vertically integrated enterprises, or cooperating groups with vertical alliances or contracts because of the integration of decision making along part or all of the chain from breeding through to processing. However, development of TRM is likely to be much more challenging than TGRM. There is one key critical control point (CCP) for TGRM, i.e. mate selection at joining time. Other CCPs for TGRM involve culling, castration and semen purchase phases, but these are all based on provisional mate selections. On the other hand, CCPs in TRM could include mate selection, drafting at various ages, stocking rates, fertiliser and feed use, timing of facilities use, and many, many other decision points. Moreover, whereas the model of genetic effects and gene transmission in TGRM is relatively straightforward, the bio-economic models underpinning TRM will be more complex and varied.

Notwithstanding this, the tactical decision making approach inherent in TRM will make a useful framework in which to place the fruits of scientific and practical research from the CRC, and make them, by definition, immediately applicable for practitioners in the beef industry chain.

A TRM example

This example relates to a very simple scenario for feedlotting of cattle. It is set up to illustrate the principles involved in TRM, and is not supposed to represent an actual application. However, its relevance to real life is quite apparent. A line of steers from a small breed enters the feedlot on day 0, averaging 160 kg liveweight. This is indicated in Figures 7 and 8.

The relationship between feeding and growth used to help generate Figures 7 and 8 has been determined using the model of Professor James Oltjen (pers. comm.). In Figure 7, feeding level was fixed at a single level (proportion of previous day's liveweight) throughout the life of each single cohort. Feeding level after target date played no role in the objective function. An evolutionary algorithm (see for example, Price and Storn 1997) was used to optimise parameters that drive grouping pattern, drafting dates and feeding level for prevailing cohorts.

The objective function to be optimised contained 4 components: (i) cost of management per independently managed cohort per day; (ii) closeness to meeting target weights on specified days; (iii) the same for body fat weights; and (iv) overall food conversion efficiency, across all lines, measured as total growth in liveweight to target dates divided by food consumed to these dates.

The relative weightings on these components are shown as b_Manage, b_WT, b_Fat and b_FCE in Figures 7 and 8,

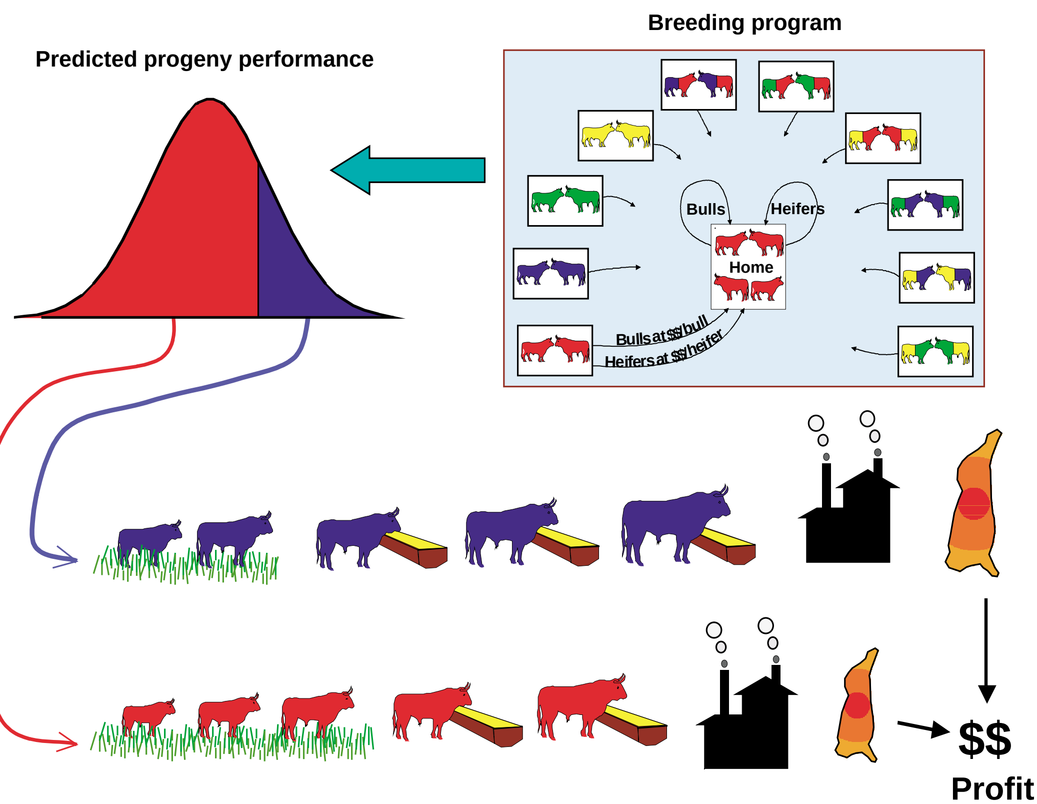

Figure 6. Total Genetic Resource Management (TGRM) has provided a decision-invoking tool for the breeding program. It is possible to let a full supply-chain model predict dollar profit, and use this to drive TGRM solutions. However, we can adopt the same decision-invoking philosophy for all key critical control points in the chain, and hence move to Total Resource Management (TRM).

and these have been scaled to equal unity for typical conditions.

In Figure 7, all target weights are essentially met. The lower weight targets are overshot slightly because of the favourable effect of this on efficiency. Lowering the weighting on target weight (b_WT) would increase this effect.

In Figure 8, a test run has been made to illustrate the fact that liveweight and body fat can be manipulated with some independence through control of diet over time. Just 2 feeding level decision periods are enough to illustrate that we can target 2 outcomes that break the trend between liveweight and body fat: (i) a high-weight-low-fat line is achieved through high feed intake followed by low feed intake; and (ii) a low-weight-high-fat line is achieved through low feed intake followed by high feed intake.

The program has deduced these feeding regimes in reaction to the targets set. This is a trivially simple example, but it serves to illustrate that the evolutionary algorithms underlying this TRM code can work to satisfy targets declared. Of course, results are contingent on the underlying feeding and growth model used, and refinements to this model will be made as a result of ongoing research in the new CRC for Cattle and Beef Quality.

The practical mode of implementing such a tactical approach will be *ad hoc*, making new runs before key decision steps and/or as new information becomes available. This could mean daily runs for a real example. This *ad hoc* approach to decision making is not short-sighted, as at each

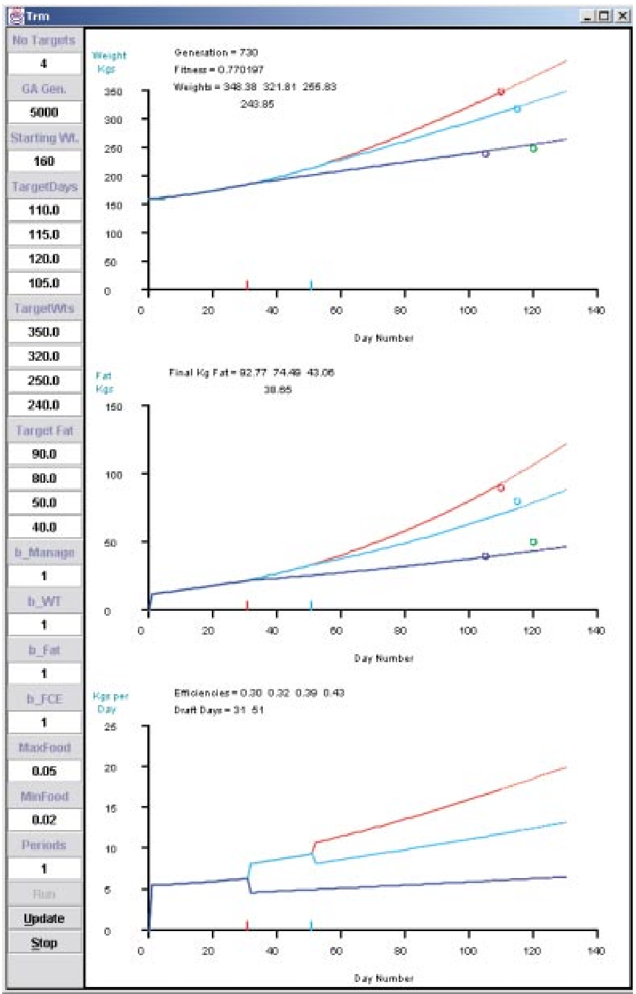

Figure 7. A Total Resource Management (TRM) example run to optimise management and feeding in a tactical manner. This is a screen capture from prototype TRM software. The top set of curves shows growth in liveweight, the middle set shows growth in total body fat, and the bottom set of curves show daily food consumption, calculated each day as a proportion of the previous day's liveweight. The 2 sets of 4 circles show the target liveweights and fat weights for the 4 target slaughter dates.

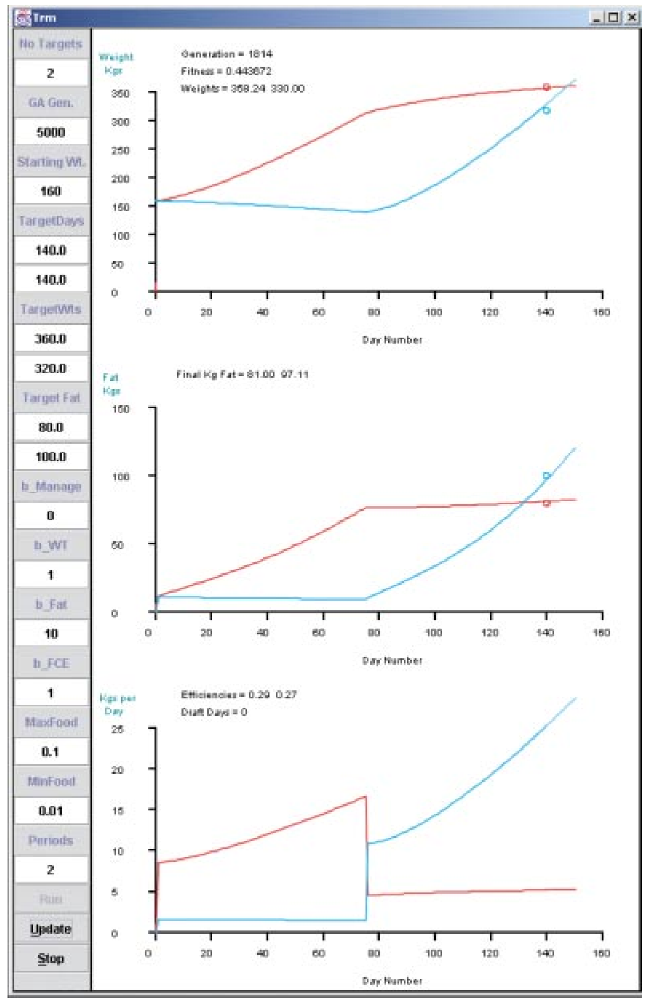

Figure 8. A Total Resource Management (TRM) example run in which antagonistic targets of high weight and low fat (and also vice versa) have been set. The properties of the underlying model have been exploited by the evolutionary algorithm used for optimisation, and the result has been achieved by manipulation of feed intake in the 2 lines.

stage the consequences of decisions are monitored along the full industry pathway, or as much of that pathway as can be predicted or modelled. As stated above, the example used here is highly simplified, and for illustration only, although useful extensions are readily apparent.

It would be valuable to start the model at an earlier stage in the production cycle so that cohorts of young stock could be bred and backgrounded for feedlot entry at times more appropriate to contracted weights and dates. Drafting into variable-sized lines would be valuable, with proper account taken of variance within group and the impact of drafting according to liveweight on the mean weights and distributions in the resulting new cohorts. The objective function should also handle factors such as desired body composition, availability of feedlot spaces and target market weights.

Cattle management techniques to improve feedlot performance

'Backgrounding' is the growing out and nutritional management of recently weaned cattle to produce young cattle meeting feedlot entry specifications. It also involves husbandry practices that ensure health and welfare in the feedlot. CRC research has clearly shown that management strategies imposed during the weaning and backgrounding phases of an animal's life can have significant impacts on feedlot performance (Burrow and Dillon 1997; Fell *et al.* 1998, 1999).

In one study, steers weaned in yards had better weight gains and less sickness when they subsequently entered the feedlot than matched groups of steers weaned in a paddock. Another group that was yard-weaned and provided with some training during the weaning period performed no better than the straight yard-weaned groups and their health was not quite as good (Fell *et al.* 1998). The yard-weaned and yard-trained cattle had a significantly higher weight gain in the first month in the feedlot and over the 90-day feeding period than the paddock-weaned control groups. There was no difference between the groups in pre-feedlot weight gain. The yard-trained groups were not significantly different from yard-weaned groups. Vaccination with an experimental vaccine against bovine respiratory disease (BRD) also significantly improved weight gain over the first month and over the 90-day feeding period. The combination of yard weaning and vaccination produced the highest weight gains overall. There was consistently lower morbidity in the yard-weaned groups compared with paddock-weaned controls. The morbidity in yard-trained groups was more variable, but overall it was intermediate between yard-weaned only and paddock-weaned groups. The method of weaning in small yards, coupled with the appropriate use of effective BRD vaccines 1–2 months before feedlot entry, was shown to minimise sickness due to early respiratory disease and to improve productivity in the feedlot. Associated benefits are reduced risks of antibiotic residues and of animal welfare problems. The procedure was clearly cost-effective, with an increase in gross margin of up to \$33 per head, while costs increased by \$5–15 per head. Benefits to the beef industry were estimated to be \$8 million by 2001.

The best explanation for these (yard-weaning) effects is that the procedure leads to better adaptation to a feedlot environment later in life. This means that such cattle do not experience the high stress levels (as shown by elevated cortisol profiles) in the feedlot that paddock-weaned cattle do which predisposes such animals to lower feed intake and higher susceptibility to bovine respiratory disease.

CRC outcomes targeting changed management practices by industry have generally been extended to industry by CRC through use of traditional linear technology transfer methodologies. However, there is limited, unsubstantiated evidence that a more effective approach to adoption of such results may be through direct targeting of feedlot operators or stock and station agents, to demonstrate the effectiveness of the new management practices. Those agents have the capacity to apply economic incentives to producers who are prepared to change their management practices to the benefit of the feedlot enterprise. Producers receiving a direct premium for cattle that are managed according to a predetermined set of guidelines before entry to the feedlot will more readily adopt changed practices (B. M. Bindon and R. J. Atkin pers. comm.).

Vaccines directed at bovine respiratory disease (*BRD*)

The CRC has produced a novel vaccine against *Pasteurella hemolytica*, a major causative agent of 'shipping fever' in cattle. In a large field trial in a 50000-head feedlot, the vaccine saved the enterprise \$4.5 million in reduced deaths, sickness and lost production. A Phase I killed product is being commercialised by AusVac, an Australian pharmaceutical company (CT Prideaux, C Lenghaus, D Schafer and ALM Hodgson pers. comm.). A Phase II subunit vaccine is also under development. Another inactivated CRC vaccine against pestivirus, a contributing agent to bovine respiratory disease and infertility, is being commercialised by the Commonwealth Serum Laboratory (CSL). These vaccines are a 'first' for Australia as there are no vaccines for these diseases, which cost the Australian beef industry about \$7 million per year. Commercialisation and adoption of these products will be undertaken directly by the pharmaceutical companies under licence from the CRC.

Reduced use of antibiotics for production purposes

The CRC's outcomes will lead to a reduced need for antibiotic treatment of cattle for production purposes. This will be of inestimable value in preserving our beef export reputation. The CRC's 'pre-boosting' research will combat sickness of cattle at feedlot entry. The CRC's new vaccines against respiratory diseases will further obviate the need to treat cattle with antibiotics. Finally, the CRC has developed new techniques to measure and predict 'immune competence' (that is, the animal's inbuilt mechanisms to avoid infection). These tests ensure that only cattle with high levels of disease resistance are exposed to stressful environments. This means less sickness and reduced need for use of antibiotics. Collectively, the strategies will help Australia maintain the 'residue-free' status of Australian beef in discerning domestic and export markets.

Improved strategies for use of hormonal growth promotants

A new hormonal growth promotant (HGP) strategy involving 3 implants per year was developed by the CRC to extend the duration of effect (see Hunter *et al.* 1998, 2000, 2001). An additional 40-kg liveweight gain per year was achieved when compared with a single HGP implant. The net value of this strategy was $22–$33 per head. Use of the improved strategy is being promoted particularly to the northern beef industry and the feedlot sector through development of close alliances with agribusiness firms manufacturing the products. Adoption of the new practices is limited by 3 factors, none of which can be readily overcome considering the use of HGPs only. These factors are the following: (i) the ban on use of HGPs by one of Australia's key markets (the European Union), which prohibits the sale to the EU of any beef product from cattle that have been implanted with HGPs at any point in their lives; (ii) the push by some producers to develop organic beef products, that by definition cannot be assisted by the use of any chemical or hormonal treatments; and (iii) the difficulty of mustering cattle in extensive areas of Australia specifically to administer HGPs to maximise the growth-promoting properties of the newly developed strategy.

Technologies to improve feedlot waste management

The CRC, together with MRC/MLA, has invested substantial resources to ensure that intensive agriculture systems, such as feedlots, can operate with sustainable re-use of waste products. The work demonstrates that acceptable levels of effluent, high in phosphorous and other nutrients, can be recycled by forage cropping strategies through a build-up of carbon levels by increasing soil organic matter. Experimental results from the CRC's programs in this area are mainly delivered to industry via 3-day workshops on 'production and environmental monitoring in feedlots', specifically targeted to professionals working in positions involving management and regulation of environmental issues. Workshop participants come from across Australia from a broad section of industry, including lot feeders, scientific researchers, regulators (Environmental Protection Authority) and local and state government authorities. CRC strategies for the extension of outcomes from feedlot waste management research are shown in Figure 9.

Marketing strategies

Meat Standards Australia

Meat and Livestock Australia recently developed a national meat-grading scheme called Meat Standards Australia (MSA; Ferguson *et al.* 1999; Polkinghorne *et al.* 1999; Thompson *et al.* 1999*a*, 1999*b*) for use on the Australian domestic market initially, but with the intention to

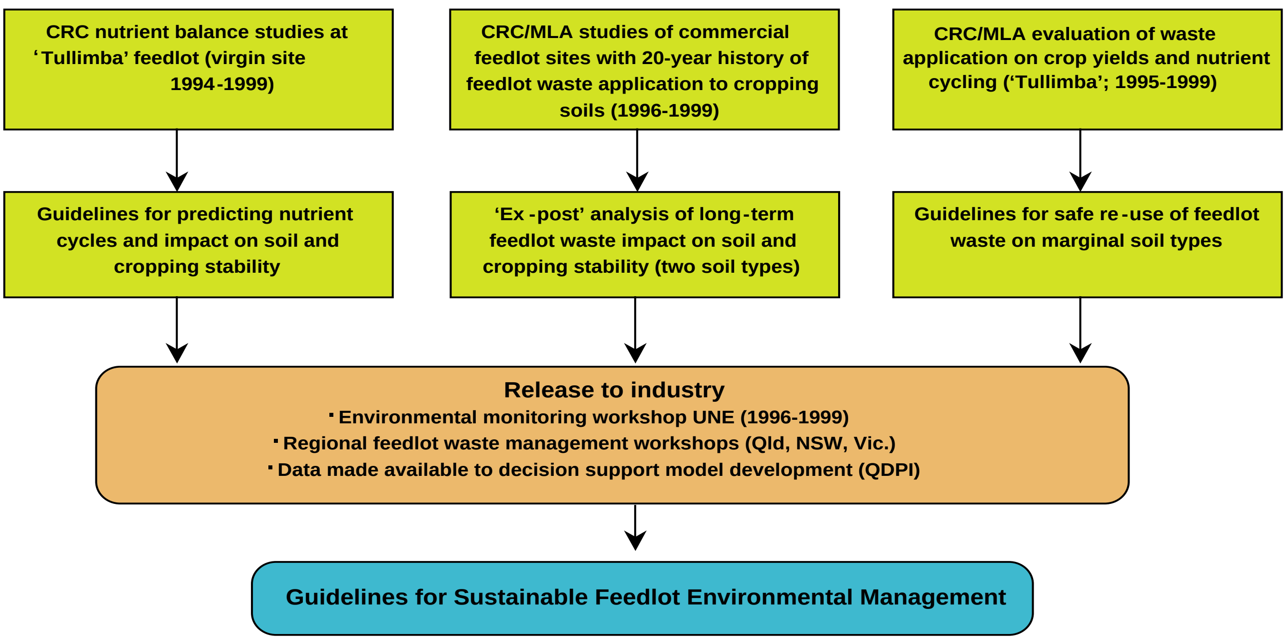

Figure 9. CRC strategies to arrive at guidelines for sustainable re-use of feedlot waste.

extend its use into Australia's export markets. The MSA approach differs in 2 important aspects from previous meat-grading schemes. First, MSA focuses on providing a guarantee of eating quality to the consumer. To this end, a large consumer-testing program was implemented, the results of which were used to set the grading standards. Second, MSA takes a total systems approach to grading beef, through control of all important factors that impact on beef quality from the production, processing and value-adding sectors of the beef production chain, rather than relying solely on carcass assessment. The MSA grading scheme is based on the principles of Palatability Assurance at Critical Control Points (PACCP). Results from various CRC experimental programs have been integrated into a model to predict eating quality of beef, as a basis for the implementation of a cuts-based grading scheme in the Australian domestic market.

The emergence of MSA and the requirement for compliance with specific production and processing pathways provides a valuable incentive for uptake of management practices that more precisely meet end-user specifications. It provides a direct vehicle for release of CRC results to all sectors of the beef industry chain, including producers, feedlotters and processors.

The Meat Standards Australia (MSA) grading scheme has gone through a rapid evolution. Consumer sensory testing for the development of the carcass pathways commenced in June 1997 and in November 1997, the first MSA carcass pathways were released for use in a pilot study undertaken in Brisbane. Following this, there were a number of modifications and additions to the carcass pathways as new results emerged from the consumer testing. In mid-1998, the concept of extending the carcass-based grading scheme to a cuts-based grading scheme was initiated. Over the next 6 months, consumer tests on individual cuts from several experiments that incorporated different cattle breeds from different finishing systems and post-slaughter treatments were conducted. The results from these experiments underpinned the development of a cuts-based grading system that was introduced to the Australian domestic market in June 1999. The new scheme provides a significant increase in the accuracy of predicting the palatability of meat. Moreover, it provides the ideal framework for a new system of value-adding and accurate end-use labelling of meat for consumers.

The cuts-based model predicts the eating quality of individual cuts and incorporates effects for *Bos indicus* content, carcass-hanging treatment, sex, carcass weight within ossification score, marbling score and ageing and cooking technique.

Table 1 shows the regression coefficients for the change in palatability (CMQ4 score) with increased *Bos indicus* content by muscle. The data indicated that the effect was linear over the entire *Bos indicus* range, but the decline in palatability interacted with muscle, with increased *Bos indicus* content having the greatest effect for the fillet (*M. psoas major*), cube roll and striploin (*M. longissimus*). These muscles comprise the low connective tissue cuts associated with the spinal column in the carcass. For these muscles, a decrease of about 10 points on a 0–100 palatability scale was found over the range of 0–100% *Bos indicus* content. These results indicated that it was not appropriate to apply a *Bos indicus* effect based on the striploin across all muscles of the carcass. Further taste panel tests are underway to validate the coefficients for a wider range of muscles and to test whether there is an interaction between *Bos indicus* content and ageing rate.

The CRC's northern crossbreeding project based on Brahman dams demonstrated the sire and breed effects on

Table 1. The regression coefficients for the effect of *Bos indicus* content on the palatability (CMQ4) score of samples ranked in order of the magnitude of the effect and after adjustment for cooking, hanging, marbling and ossification scores and their interactions (derived from Thompson *et al.* 1999)

Primal cut	Muscle	Regression coefficient (b)[A]	Standard error of b[A]	Signif.
Tenderloin	*Psoas major*	–0.09	0.020	$P<0.0001$
Cube roll	*Longissimus thoracis*	–0.08	0.021	$P<0.0001$
Striploin	*Longissimus lumborum*	–0.08	0.020	$P<0.0001$
Brisket	*Pectoralis profundus*	–0.05	0.038	n.s.
Spinalis	*Spinalis dorsi*	–0.05	0.036	n.s.
Eye round	*Semitendinosus*	–0.04	0.022	$P<0.10$
Knuckle	*Rectus femoris*	–0.03	0.019	$P<0.10$
Rump	*Gluteus medius*	–0.03	0.020	n.s.
Blade	*Triceps brachii*	–0.02	0.020	n.s.
Topside	*Semimembranosus*	–0.01	0.018	n.s.
Oyster blade	*Infraspinatus*	–0.01	0.026	n.s.
Outside flat	*Biceps femoris*	0.01	0.018	n.s.

[A]b refers to the change in MQ4 score (scale of 100) per 1% increase in *Bos indicus* content.

retail beef yield percentage, the percentage of intramuscular fat (marbling) and shear force (an objective measurement of beef tenderness). These traits will no doubt become the cornerstone of value-based marketing when implemented. Furthermore, 50% of the *Bos indicus* animals were proven to be productive in the northern environment while at the same time being able to meet MSA grading standards.

The CRC's involvement in the design of the MSA program and the analysis of the data has identified the need for all sectors of the industry to focus on production 'pathways'. Critical to this is the need to maintain adequate levels of nutrition with backgrounding, now a common practice within the industry. Research in this area has also shown the effect growth checks have on carcass composition and particularly on fat distribution. This too will be an important determinant under value-based marketing.

Overwhelmingly, the most effective method of providing end-user information on MSA has been through the MSA web site, maintained by CRC staff (http://msa.une.edu.au)

Patterns and frequency of use of the web site have been monitored since its inception and indicate that this site is an essential source of information for both Australian and international end-users aiming to improve the eating quality of beef.

Education, training and technology transfer strategies

The aims of the CRC's education and industry training programs are to: (i) increase the scientific expertise available to the Australian beef industry; (ii) increase the knowledge base in all sectors of the beef industry; and (iii) transfer the CRC's outcomes to end-users in all industry sectors by means of collaborative research, extension and communication.

The CRC's education and industry training programs have elected to make extensive use of new technology, with interactive teaching and training programs delivered using computerised systems. Industry recipients in remote areas are now actively sourcing many of the new technologies in animal breeding and genetics, growth and nutrition and health and welfare via the Internet. Previously, the rate at which beef operations in remote areas adopted new technologies was relatively low, probably reflecting lack of access to updated information and, additionally, the format in which this information was available. However, electronic delivery can target individual remote clients and clients in small groups following the increasingly popular 'cottage computing' local facilities or clients in larger groups directly supported by instructors. The CRC is beginning to capitalise on the latest delivery mechanisms, including electronic transfer of information via email, the Internet and CD-ROM. Development of computer-based training material presents a great challenge. There must be a distinct advantage over paper material to make this worthwhile for the end-user. The advantages that can be generated relate to fast navigation over a wide range of information, guidance tools, scenario building tools and decision aid tools. These components need to be tightly linked in a simple and friendly framework.

The CRC provides specialised, applied training in postgraduate research, with supervision of students being provided by CRC scientists in conjunction with UNE academic staff. This involves both PhD and Research Masters levels. The PhD program ensures relevant specialised research skills are available to industry, with emphasis on projects related to improving beef quality and safety.

Additional subjects have and are continuing to be developed for delivery to undergraduate students and coursework postgraduate students at UNE. Some subjects are also made available through other universities. These will be used to further develop and expand the CRC program of certificate level courses for industry. The highly successful and innovative Certificates in Rural Science in Feedlot Management and Meat Science and Technology will be continued and upgraded to cater for developing industry needs. Enrolments in these new subjects have exceeded expectations and uncovered an untapped market for management level education for the feedlot and pastoral industries. Subject areas covered at a level that satisfies minimum university standards, while being achievable for industry personnel, are a unique achievement of the CRC.

A program of specialised short courses and workshops has been developed, with CRC scientists and education staff providing the teaching. The proven format of 3–4-day short courses presented in a program format of theory and technical information in morning sessions, followed by practical hands-on sessions in the afternoon, satisfy an intermediate course demand. This format provides more detail than can be covered in a 1-day field day, without the need for a commitment to a registered medium- to long-term course. This is best demonstrated through courses such as the Armidale Feeder Steer School that has operated over the past 5 years and attracted an annual audience of 80–100 lot feeders, beef producers and agribusiness personnel. These schools involve practical sessions integrated with the latest innovations and scientific research and are supported with high-quality printed proceedings.

Technical and Further Education (TAFE) and vocational teaching modules act as base courses for students' articulation into higher qualifications with Universities in all states. TAFE organisations across states offer beef production and food service courses. Learning materials produced by the CRC in the areas of live-animal assessment, food service, meat processing, meat marketing and meat retailing provide the base for continued integration and cooperation with TAFE.

Communications with industry are by direct involvement of CRC scientists and extension specialists, geared through the extension arms of the CRC core partners and alliances with industry organisations. During the life of CRC I, the following education, training and technology transfer achievements were recorded: (i) 32 postgraduate students; (ii) 336 participants in 4 feeder steer schools; (iii) 172 enrolments in certificate courses; (iv) 941 enrolments in TAFE courses; and (v) 717 publications.

Evaluation of the success of delivery of CRC outcomes

One of the key deficiencies of the CRC's strategies for delivery of outcomes was a failure to undertake a genuine benchmarking exercise at the outset of the CRC, to subsequently allow a genuine evaluation of the effectiveness of the strategies for the adoption and utilisation of the outcomes. However, feedback from industry stakeholders has provided some opportunity for reflection on the most effective strategies.

Without doubt, the most effective method of ensuring adoption and utilisation of CRC outcomes has been end-user input to the initiation, design, conduct and funding of the research programs. CRC sponsors involved in such participative approaches were early and immediate adopters of technologies. In some cases, they also clearly demonstrated they were prepared to take considered risks to gain a competitive advantage through implementation of technologies, even before the researchers were confident of the outcomes. They also actively sought CRC results and were generally unforgiving of delays in production of information that might impact on the conduct of their businesses. This was a genuine lesson for the CRC, with a dedicated, ongoing and concerted effort required to maintain the necessary flow of information to CRC sponsors. However, it would be remiss of us to conclude that the preferred method of extension should be the use of a participative 'bottom-up' approach to ensure industry implementation of research results. In general, CRC sponsors were beef industry stakeholders with a track record of past innovation and early adoption of technologies. Their involvement as sponsors of the CRC simply represented a logical and business-based extension of their earlier involvement with research and development agencies. The participative approach to their inclusion in the initial CRC program, however, did provide increased support from many of the same sponsors for the renewed CRC program and leads us to conclude that this approach should underpin all future research and development projects.

Other approaches that have yielded early and successful adoption of CRC outcomes include: (i) Methods that provided positive feedback to end-users by way of economic incentives to stakeholders who changed their genetics, production or processing methods to achieve a more consistent beef product (e.g. MSA; weaning and backgrounding strategies to improve feedlot performance; effective use of processing technologies such as electrical stimulation or ageing of beef to guarantee consumer satisfaction with branded beef products such as Certified Angus Beef). (ii) Technologies that lead to quantifiable benefits to particular groups of stakeholders (e.g. collaborating seedstock breeders who perceived an ability to rapidly improve genetic progress towards the most commercially relevant traits through adoption of both quantitative and molecular genetic technologies; use of vaccines that clearly reduce either mortalities or morbidities). (iii) Methods that integrate outcomes from a number of different disciplines or technologies (e.g. TGRM that incorporates BREEDPLAN EBVs for all traits, a Breed Object $Index and possibilities for use of specialist reproductive technologies to accommodate all the key issues in decision-making for animal breeding programs; TRM that will integrate genetic, nutritional, management and processing factors into optimal decisions for all sectors of the beef production chain). (iv) Increasingly, web-based information sources and delivery technologies are proving to be effective mechanisms to ensure acceptance and utilisation of research results. (v) The CRC's structured educational and training programs have clearly filled a deficiency for training at all levels of industry. This is positive news for the Australian beef industry, as Kilpatrick (1996) reported a significant relationship between farm profitability and participation in training events such as field days, seminars, conferences and industry meetings. Kilpatrick (1996) also found that farmers who participate in such training events are more likely than others to make changes in their practice that improve or are expected to improve long-term profitability or viability.

Although traditional technology transfer approaches used by the CRC did not appear to result in high levels of demonstrated change in practices, beef industry stakeholders still need access to reliable scientific information. Traditional technology transfer approaches used by the CRC have provided a wealth of extremely valuable scientific results on which beef industry stakeholders can reliably base business decisions.

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Received 16 March 2001, accepted 5 July 2001