Industry application of marbling genetics

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Abstract. Improved marbling performance has been recognised for many years as an important objective for the "high quality" export sector of the Australian beef industry. Over the last 5 years there have been several developments that have provided breeders with significantly better information on which to base breeding decisions aimed at improved marbling performance. These include the application of real-time ultrasound scanning for intramuscular fat percentage (IMF%); the derivation of genetic parameters involving IMF%; the enhancement of BREEDPLAN to incorporate IMF% in multi-trait genetic evaluation; and, the industry adoption of selection index technology (via BREEDOBJECT) to assist in optimal multi-trait selection including marbling performance.

It is argued that a major constraint to the genetic improvement in beef palatability traits, including marbling performance, has been the inadequate communication of effective market signals and poor information flow through the beef supply chain. This situation is unlikely to change unless the industry achieves a greater degree of vertical co-ordination and improved linkage across the supply chain from the producer to the consumer. There is a need for the implementation of genuine value based marketing systems that provide an appropriate financial incentive for seedstock and commercial beef producers to adopt breeding and management strategies that emphasise the improvement of beef palatability and marbling. The application of gene marker technology will provide future opportunities, as well as additional challenges, in the quest for achieving improved marbling performance.

Keywords: marbling, intramuscular fat percentage, ultrasound scanning, breeding objectives, genetic improvement, multi-trait selection, value-based marketing.

Introduction

Improved marbling performance has been recognised for many years as an important objective for the "high quality" export sector of the Australian beef industry. Feedback from processors and exporters has shown that significant variation in marbling performance exists among animals. However, until recently, beef producers have not had adequate tools or information on which to base breeding decisions that result in effective genetic improvements in marbling performance. On the contrary, breeders have traditionally either ignored marbling performance in their selection decisions, or have based their decisions on imperfect anecdotal information on which breeds and bloodlines have superior marbling performance.

Fortunately, over the last 5 years there have been several developments that have provided breeders with significantly better information on which to base breeding decisions aimed at improved marbling performance. The purpose of this paper is to briefly review these developments and to discuss the likely limitations on future application of effective genetic improvement programs for improved marbling performance.

Developments in the application of marbling genetics

Ultrasound scanning for IMF%

The development of real-time ultrasound scanning for intramuscular fat percentage (IMF%) during the 1990s was a significant step forward to enable widespread genetic evaluation and selection for improved marbling performance (Graser *et al.* 1998). The extension of the real-time ultrasound scanning technology to include measurement of IMF% was rapidly adopted by accredited industry ultrasound technicians in Australia and enthusiastically accepted by many seedstock producers across several breeds (particularly breeders of Angus, Murray Grey, Shorthorn, Hereford, Poll Hereford).

Since the commencement of routine recording of real-time ultrasound IMF% data by the National Beef Recording Scheme in 1998 there has now been over 79,000 records collected, spanning 18 breed society databases (J. Allen, ABRI, pers. comm.).

The adoption of real-time ultrasound technology for measurement of IMF% has also been demonstrated in recent years in the Angus breed in USA. During the 3 year period between 1998 and 2001 over 157,000 ultrasound IMF% images were submitted for genetic evaluation. In comparison, less than 62,000 abattoir marble score records have been collected since the commencement of the American Angus Association carcass genetic evaluation program in 1972 (J. Crouch, pers. comm.).

Multi-trait genetic parameters including IMF%

One of the important early outcomes of the Cooperative Research Centre (CRC) for the Cattle and Beef Industry (Meat Quality) was the generation of the necessary structured data for the calculation of robust estimates of genetic parameters for various carcass and meat quality traits (Dundon *et al.* 2000).

The CRC "Straightbreeding Project" involved the generation of sire identified progeny groups from seven breeds (Angus, Belmont Red, Braham, Hereford, Shorthorn, Murray Grey, Santa Gertrudis). Collation of early results from this extensive progeny test program resulted in a database containing detailed carcass and meat quality measurements on over 4,000 progeny. This database, together with limited available field data, was used to derive the initial estimates of heritabilities and genetic correlations necessary for the inclusion of IMF% as a trait in Breedplan (Reverter *et al.* 2000). These initial genetic parameter estimates have underpinned the calculation of carcass EBVs in BREEDPLAN for the last 3 years. Revised estimates, based on more recent analyses of the completed CRC database, are due for incorporation into BREEDPLAN in late 2001 (D. Johnston, pers. comm.).

Development of IMF% EBVs

The derivation of genetic parameters involving IMF%, and the establishment of real-time ultrasound scanning for IMF% in industry herds, paved the way for the development and implementation of a new version of BREEDPLAN (Version 4.1) that included Estimated Breeding Values (EBVs) for IMF% together with newly defined EBVs for other carcass traits (i.e. Eye Muscle Area, Rib and Rump Fat and Retail Beef Yield) adjusted to a 300kg carcass weight end-point (Johnston *et al.* 1999). The first "Trial" BREEDPLAN EBVs for IMF% were published by the Angus Society of Australia in October, 1998 (ASA 1998). This was quickly followed by the publication of Breedplan IMF% EBVs by several other breeds in early 1999.

In addition to utilising ultrasound IMF% data, the revised multi-trait BREEDPLAN model (Version 4.1) makes use of available chemical IMF% or marbling score data collected directly from carcasses. The flexibility of the BREEDPLAN model is such that multiple sources of overseas genetic evaluation information on "immigrant" animals can be effectively utilised. For example, in the Angus breed, where substantial use has been made of North-American genetics, published Expected Progeny Differences (EPDs) for marbling performance on animals from USA and Canada, and available real-time ultrasound scan EPDs for IMF% from USA, are "imported" into the BREEDPLAN analysis. Figure 1 illustrates the various sources of potential information used in the calculation of carcass EBVs under the multi-trait BREEDPLAN model.

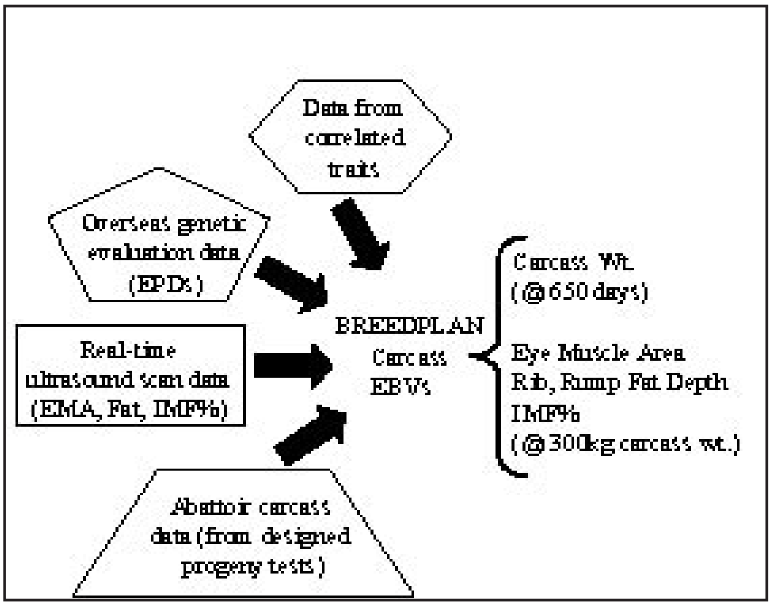

Figure 1 Sources of information contributing to carcass EBVs in Breedplan (Sundstrom 2001).

Marbling score data from commercial slaughter programs

While the multi-trait BREEDPLAN model can make use of "direct" abattoir marbling score data, to date there has been very limited amounts of this data included. Most slaughter cattle come from commercial herds that either use multiple sire joining or fail to record individual sire details. Even in cases where individual sire identification is known animals are often slaughtered in batches depending on their degree of "finish". Also, in many abattoirs individual carcasses are often not routinely matched to live animal identification. Unlike seedstock herds where across-herd genetic "links" are common due to the use of AI or introduction of outside recorded bulls, commercial herds generally have inadequate genetic "links" to provide useful comparative data for genetic evaluation purposes. In many cases where marbling score data has been collected on potentially useful animals for genetic evaluation it has been scored using simple numeric "AusMeat" scores rather than on a "graduated" scale such as that used by MSA or USDA. For these reasons, designed progeny tests with strict identification and slaughter protocols in place are necessary for the generation of abattoir marbling score data useful for genetic evaluation.

Valuing differences in IMF% EBVs

In order to estimate the affect of an increase in average IMF% on marbling performance it is necessary to make some assumptions about the relationship between the traits and their underlying distributions. In the example described below it is assumed that the discrete marbling score units are linearly related to IMF%, and that IMF% is normally distributed with a standard deviation of 0.9 units. Further, it is assumed that marbling score 1 is equivalent to about 3.0% IMF and that each additional marbling score is equivalent to a further 1.5% IMF. In reality, the relationship between IMF% and marbling score tends to be variable and non-linear (D. Johnston, pers. comm.), and the variability of marbling scores tends to vary across different groups of animals. Nevertheless, the example still serves as a useful guide to the potential magnitude of benefits obtained from selection for increased IMF%.

Suppose, for example, that the average IMF% of the progeny of particular sire ("Bull A") with an $EBV_{IMF\%}$ of -0.2, under a particular feeding and management regime, was 6.0%. Given the above assumptions, we would expect that approximately 50% of the progeny would achieve marbling score 3 or better when slaughtered. From the same female herd, and under the same feeding and management regime, we would expect that the progeny of a sire ("Bull B") with an $EBV_{IMF\%}$ of +0.8 to achieve an average IMF% of 6.5% (i.e. 0.5% higher than progeny of "Bull A") with 71% of the progeny achieve a marbling score 3 or better. Figure 2 illustrates the expected distributions of IMF% and marbling score performance among progeny of "Bull A" and "Bull B".

If we follow the example further, and make some additional assumptions regarding the herd structure, the anticipated working life of the selected bulls and the market premium obtained for marbling performance, it is possible to estimate the expected additional revenue obtained across the supply chain from the superior marbling performance of the progeny of "Bull B". Suppose, for example, that the bulls were joined to 35 cows each year for 4 years and the herd achieves an average weaning rate of 90%. If an average of 7 daughters of each bull were retained each year as replacements, then each bull would be expected to produce a total of about 100 slaughter progeny. Also, assume that the average progeny carcass weight was 345kg, and premiums were obtained of 40cents/kg for marbling score 2 carcasses, and an additional 20cents/kg per additional marbling score unit. Assuming that future revenue is discounted at a rate of 7% per annum, it can be calculated that the expected Net Present Value (NPV) of the higher marbling score performance of the slaughter progeny by using "Bull B" is approximately $2,000. It can also be calculated that further potential long-term gains in marbling performance in future generations obtained from retaining genetically improved replacement females would equate to an additional NPV of approximately $680 – giving an expected total NPV of about $2,680 from using "Bull B" compared to "Bull A".

The above comparison is of course sensitive to the various assumptions used in the analysis, and ignores any genetic differences between the bulls for other traits influencing profitability. Significantly different results can be obtained by varying factors such as the assumed marbling premiums, current average marbling performance, herd structure, mating ratios etc. A further consideration is the capacity of the breeder (bull purchaser) to capture the economic benefits generated across the supply chain resulting from improved marbling performance (eg. through retained ownership, or value-based payment systems). Also, the example assumes that the decision maker is an individual commercial producer. If the producer was a seedstock breeder (i.e. selling breeding stock) then there would be additional NPV generated from the dissemination of genetically improved breeding stock to client herds.

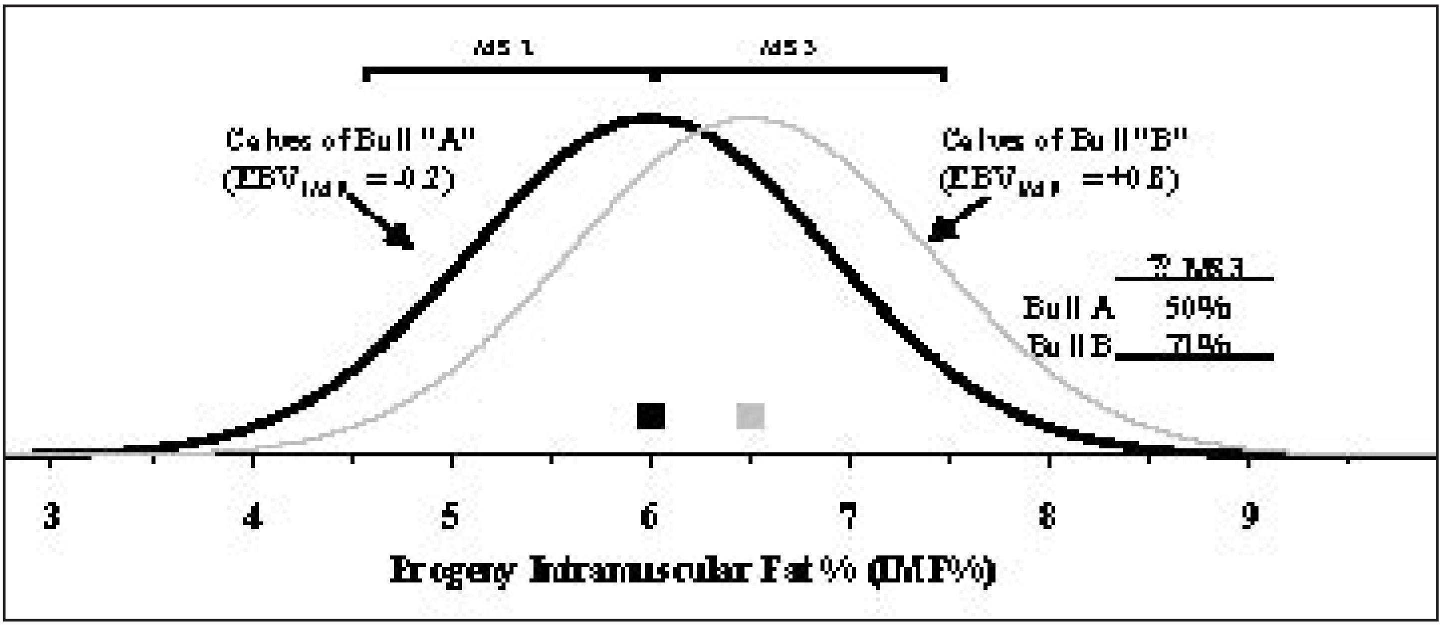

Figure 2 Example distributions of intramuscular fat percentage (IMF%) and marbling score (MS) performance for progeny of bulls with different IMF% EBVs. See text for assumptions.

Multi-trait selection including marbling performance

In determining the expected consequences of any selection decision it is necessary to account for both the direct and indirect (i.e. correlated) changes in various traits affecting herd profitability. In the case of selection for improved marbling performance we anticipate a mixture of favourable changes in carcass value plus some unfavourable changes in other traits of economic importance (eg. reduced retail beef yield). Barwick and Henzell (1999) showed how the economic value of improved marbling performance could be objectively assessed when deriving breeding objectives for individual decision makers. They described a procedure for including marbling evaluations in selection indices where marbling contributes non-linearly to the breeding objective. This methodology has been incorporated into "BREEDOBJECT", a decision support system used to derive "optimal" multi-trait selection indexes for particular production systems and market targets (Barwick and Henzell, 1998).

Coinciding with the development and implementation of IMF% EBVs in BREEDPLAN there has been a growing interest in the use of "BREEDOBJECT" derived selection indexes in the Australian beef industry. In early 1999 the Angus Society of Australia published selection indexes and associated $Index Values for example "case study" herds targeting the production of slaughter progeny for either the domestic supermarket or the Japanese B3 export market (Parnell and Barwick 1999). During the last 12 –18 months several other breed societies have developed "standard" selection indexes and published $Index Values in their sire summaries or website animal enquiry facilities.

Table 1 includes the economic values for marbling score in three case study selection indexes currently used by the Angus Society of Australia (ASA 2001). These values represent the NPV per cow joined, per year, generated across the supply chain from an increase in 1 marbling score unit, when all other traits are unchanged. These economic values are sensitive to the various assumptions used in the "BREEDOBJECT" analysis, including production costs, price premiums for improved marbling performance, current herd performance levels etc. Where possible typical values were used for a commercial herd operating in 2000-2001.

Figure 3 shows the relative economic values (REVs) for all traits included in the three "standard" case study selection indexes. REVs are an indication of the relative value of a standard amount of genetic change in each trait (i.e. standardised for different amounts of genetic variability of each trait). In these indexes, improved marbling performance accounted for 13% to 32% of the total selection emphasis. In practice, the actual emphasis placed on any particular trait will depend on the range of EBVs present among the animals available for selection.

Due to the complexity of correctly accounting for the various economic parameters and genetic relationships among traits it is unlikely that breeders will place appropriate emphasis on marbling performance unless they make use of a suitable selection index. Over the last 12-18 months an increasing number of breeders have made use of example case study

Table 1. Economic values of a unit change in marbling score for three example case study selection indexes used by the Angus Society of Australia (ASA, 2001).

Example Case Study	Net present value across the supply chain of a unit shift marbling score ($ per cow joined per year)
Japanese B3 Index	$ 49.59 /cow
Certified Australian Angus Beef™ Index	$ 22.92 /cow
Northern Terminal Index	$ 26.77 /cow

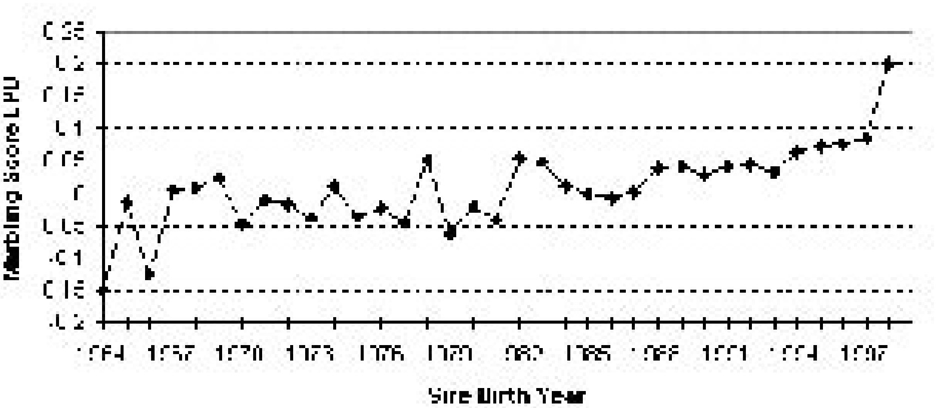

Figure 3 Relative economic values (REVs) of different traits in example case study selection indexes including marbling score in the breeding objective. (Source: ASA (2001)).

selection indexes in their breeding decisions and their seedstock marketing programs. However, there is still a major need for the development and implementation of a simple integrated decision support system that enables breeders to specify customised selection indexes more appropriate for their individual circumstances and to "optimise" the allocation of breeding females to selected sires.

Genetic trends in marbling performance

The American Angus Association (AAA) has conducted genetic evaluation for carcass traits, including marbling performance, since 1972. The genetic evaluation for marbling performance has been based on USDA marbling score assessment on animals from designed progeny test programs (AAA 2001). The trend in marbling score Expected Progeny Differences (EPDs) among sires, shown in Figure 4, indicates that Angus breeders in USA have effectively improved marbling score performance over the last 10-15 years. Due to the strong influence of North American genetics in Australia over this same period it is expected that the average marbling performance should have also improved in the Australian Angus population.

Figure 5 shows the trends in the average IMF% EBV and the average $Index Value for the example Japanese B3 Index (ASA, 2001) for the recorded Australian Angus population. The positive trend in IMF% has made a significant contribution to the genetic trend in overall profitability over this period. It is likely that the positive trend in IMF% prior to the availability of IMF% EBVs was due to the influence of imported North American genetics.

Challenges for the future

Value based marketing for marbling performance

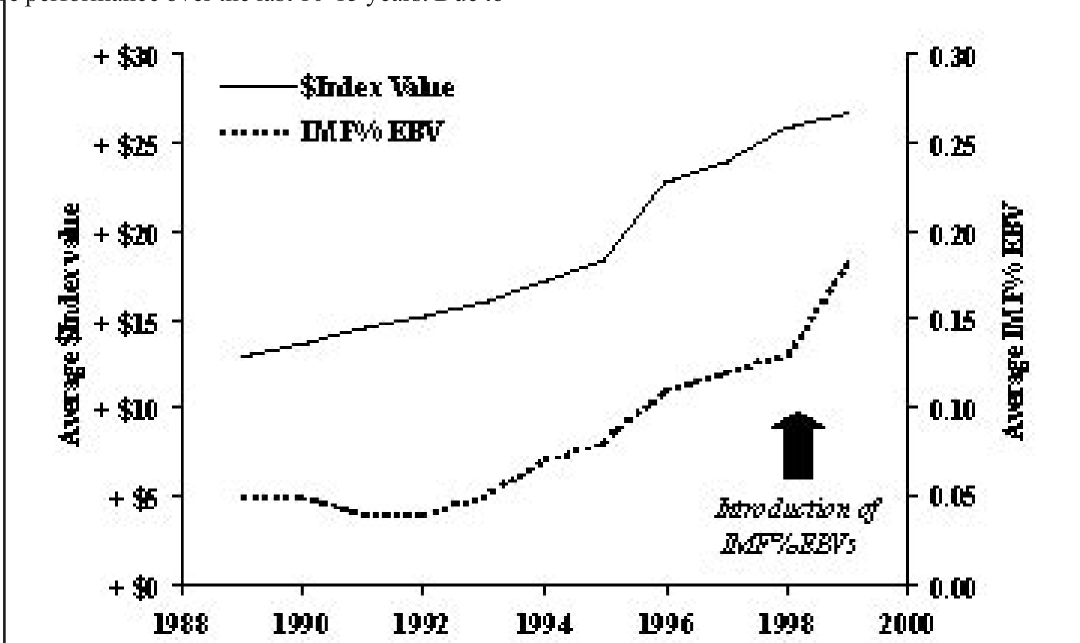

Figure 4. Trends in Marbling Score Expected Progeny Difference (EPD) among sires recorded with the American Angus Association. (Source: http://www.angus.org.)

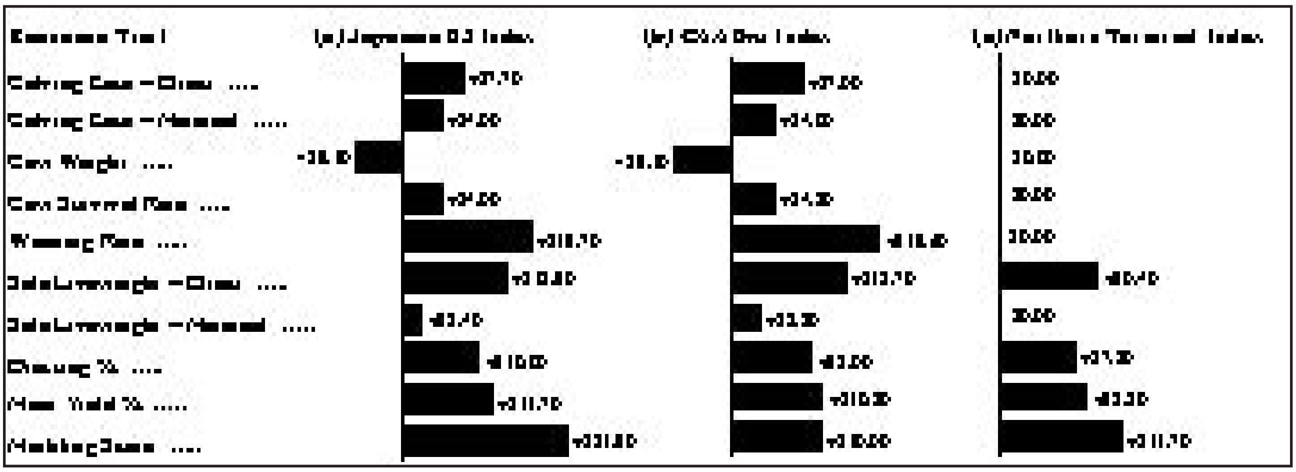

Figure 5 Trends $EBV_{\%IMF}$ and $Index Value for the example Japanese B3 Index, in the recorded Australian Angus population.

A major constraint to the genetic improvement in beef palatability traits, including marbling performance, has been the inadequate communication of effective market signals and poor information flow through the beef supply chain. In order to obtain continuity of supply lot feeders and processors have been prepared to pay "premiums" for particular breeds and "vendor lines" that have real or perceived superior marbling performance. However, these "premiums" are simply a function of supply and demand and usually represent only a small fraction of the potential extra value generated by superior marbling performance.

The Australian beef industry is characterised by a concentration of "market power" and influence in the processing and retailing/exporting sectors. In contrast, there are a large number of independent participants in the production sector, with the vast majority having very little market influence. Ideally, in any segmented supply chain there should be efficient transfer of information and market signals between and within each sector. In practice, there has been little transfer of information between sectors of the beef supply chain and market signals have tended to simply reflect the short-term dynamics of commodity supply and demand. A key reason for this has been the high degree of fragmentation and aggressive open market competition in the supply chain. A commodity trading culture is the norm with prices largely based on "averaging". Under this scenario, there has been little incentive for improvement of product quality or for the transfer of individual performance information through the supply chain (Parnell and Dent 1999).

It was suggested by Moav (1973) that open market competition among producers eventually diminishes their share of any economic benefits from the adoption of genetic improvement strategies. In this situation it is the consumers rather than producers who ultimately benefit most from genetic improvement. The formation of strategic alliances among producers, effectively reducing competition, might be a method of retaining a greater share of the benefits accrued from genetic improvement. However, compared to other sectors of the food industry, beef producers have tended to be reluctant to participate in strategic alliances. This is partly due to the strong tradition of suspicion among many beef producers of their "competitors", a strong desire to maintain independence, and a common belief that alliances will restrict their ability to pursue market opportunities.

There are few examples of successful strategic alliances in the Australian beef industry, particularly in the high quality segment of the industry where marbling performance is important. One notable exception to this situation is the relatively small AMG Gold$_{TM}$ program that delivers tightly specified branded product into the high value Japanese B3 market. This program offers retained ownership options with premiums paid on the basis of individual carcass compliance to the AMG Gold$_{TM}$ specification. Added bonuses are paid for carcasses with higher marbling scores, reflecting the higher value of these carcasses in the Japanese market.

In contrast to the Australian situation, there are numerous examples of successful alliances in the US Beef Industry. Several of these alliances have been set up as vertically integrated co-operatives involving participants from the seedstock sector through to the production, feedlot, processing and retailing sectors of the beef chain. These programs typically target high value branded products where marbling performance is an important component of carcass value. Most of the programs provide retained ownership options and provide comprehensive feedback on feedlot performance and USDA assessed carcass yield and quality.

Experiences in the US Beef Industry, and in other livestock industries (eg. the Australian lamb industry) indicate that mutually beneficial (i.e. "win-win") relationships can be achieved through greater cooperation between sectors of the supply chain and widespread adoption of the principles of value based marketing. The adoption of this degree of co-operation in the Australian beef industry will require a significant adjustment to the nature of the existing supply chain and in the way participants view their businesses. Until this adjustment occurs genetic progress in marbling and other beef palatability traits will be substantially constrained.

Use of commercial marble score data

As mentioned above, there has been very little suitable commercial marbling score data available for inclusion in genetic evaluation. Australian seedstock producers have been reluctant to invest in structured progeny test programs. Major impediments include the high cost of artificial breeding in commercial herds, the loss of animal identification from birth to slaughter (often associated with change in ownership along the supply chain), the splitting and/or sorting of contemporary groups prior to slaughter, and the lack of precision in the recording of abattoir carcass measurements. Improved linkage between sectors of the beef supply chain, and the provision of greater incentives for the genetic improvement in carcass traits (i.e. through value based marketing) would assist in overcoming many of the logistical and financial constraints to progeny testing.

While the widespread application of real-time ultrasound scanning for carcass traits has somewhat reduced the imperative for large scale investment in progeny testing, it is considered by many that direct carcass measures are still required to complement scan data in genetic evaluation. Since it is unlikely that further large quantities of "direct" carcass data will come from research projects (eg. such as the Beef CRC program) the industry will have to rely largely on "field" data for future validation and revision of genetic parameters (eg. genetic correlations) used in genetic evaluation. Widespread adoption of electronic identification, coupled with the installation of automated information systems at abattoirs, will improve the opportunities for collection of useful carcass data for genetic evaluation.

Effective utilisation of gene marker technology

As discussed by Barendse (2001) it is likely that additional gene marker tests for marbling and other meat quality traits will be developed and commercialised to the industry over the next few years. There is no doubt that gene marker information may be potentially very useful for hastening the rate of genetic progress. However, the real benefits from this technology will only be realised if the marker information is readily available to individual breeders responsible for selection and mating decisions. The impact of gene marker information will be significantly reduced if this information is restricted to isolated segments of the industry.

It is a concern that the commercialisation arrangements for the Genestar marbling test, developed using public and industry funds, are such that less than 20 percent of the test results to date are publicly available to individual decision makers. R & D providers will continue to face a difficult challenge in the future to manage the commercialisation of gene marker technologies such as to achieve widespread utilisation, whilst at the same time providing sufficient economic incentive for commercial organizations to continue the development of useful tests. Gene marker commercialisation models that have been effective in other industries may not necessarily be appropriate for the beef industry due to the dispersed nature of individual decision markers in the seedstock and commercial production sectors.

Decision support systems for optimal multi-trait selection and mate allocation

The application of selection index procedures (i.e. via BREEDOBJECT) over the last few years has been a significant step forward in simplifying the problem of balanced multi-trait selection. However, the anticipated future availability of genetic marker information for marbling and other meat quality traits will introduce another layer of complexity for breeders to contend with in their selection decisions. This will increase the need for the availability of simple decision support systems to assist in the optimisation of selection and mating allocation.

Assuming that effective value based marketing systems will be eventually implemented throughout the industry there will be even greater future focus on end-product performance. This will result in an even greater requirement for seedstock and commercial producers to have access to the necessary tools and information to practice effective multi-trait selection such as to also maintain high levels of herd productivity (i.e. reproductive and maternal performance, calving ease, early growth performance).

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