GENE MARKERS FOR MEAT QUALITY TRAITS: HOW THE INDUSTRY MIGHT USE THEM

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SUMMARY

Gene markers are a new and potentially powerful technology which will enable beef cattle breeders to more precisely target customer specifications. In the future, gene markers will be available for a range of performance, disease and conformational traits. However the most important applications of gene markers will be for traits which are currently difficult and costly to measure on breeding stock such as carcass characteristics and meat quality but which have high value in commercial cattle. Recent research has identified gene markers for a range of traits including carcass yield, marbling and tenderness. Although the markers require field evaluation in industry herds before release, it is now appropriate for breeders to consider how best to utilise gene marker technology. Three options are described here. Firstly, breeders could simply buy bulls which have been bred using gene markers. Second, breeders could evaluate gene markers within their own herds in order to establish optimum gene marker profiles for ongoing use. Third, breeders could buy bulls with defined gene marker profiles and continue breeding within their herd based on the desirable profiles. The advantages and disadvantages of each approach are discussed.

Keywords: Gene markers, meat quality, progeny test, BREEDPLAN.

GENES ARE PASSED ON FROM ONE GENERATION TO THE NEXT

The genetic material carried in sperm and eggs is made up of around 75,000 genes. Each gene has a function. Some genes can exist in multiple forms eg A_1, A_2. Such genes are responsible for individual differences in performance. Genes, in combination with the environment (nutrition, management and physical factors) determine the way in which an animal grows, develops and reproduces. An animal inherits two copies of each gene, one from the father and one from the mother. These copies may be identical or different in form. A parent passes on only half of its genes to each offspring ie one member of each pair of genes.

GENE MARKERS DETECT THE DIFFERENT FORMS OF GENES

Gene markers may be considered as tags which allow the inheritance of the different forms of genes or gene variants to be followed. Gene markers can either be adjacent to or within the gene (Figure 1). Where a marker flanks the gene, particular forms of the marker will be associated with specific gene variants. However, such associations can be broken down over generations and therefore need to be redefined at intervals. Specific associations, ie which form of the marker is associated with which form of the gene may also vary between family lines. Thus, unless the marker is extremely close to the gene, flanking or linked markers will be generally less accurate and more complicated to use in practice than markers for the gene variants themselves.

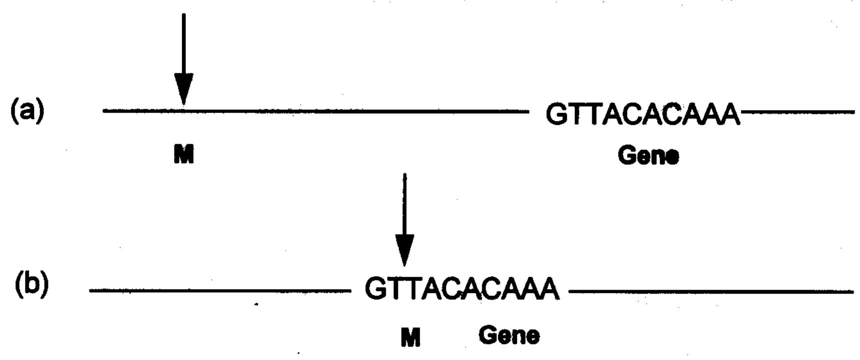

Figure 1. Gene markers (M) close to (a) or within a gene (b). For (b) the gene variants can be detected directly.

The accuracy of prediction using gene markers will also vary with the trait. For simple genetic traits (eg red/black coat colour), accuracy will be high eg more than 95%. For more complex traits such as growth and carcass traits, overall accuracy is expected to be medium eg 50-80%, since not all genes affecting the trait will be tagged with markers. In most cases, gene markers will be more accurate predictors of genetic merit when the pedigree of animals is known. This is especially true for flanking markers (Fig 1a).

Tests based on gene markers can be used to predict the breeding performance of individual animals in their own lifetime with respect to specific traits. The tests can be carried out on a wide range of tissue samples such as blood, skin, hair or muscle collected at any age after conception. Testing at the embryo stage is also an option, opening the way for rapid changes of gene frequency especially when combined with reproductive techniques such as *in vitro* production of embryos using heifer calves which reduce generation interval (Davis *et al*, 1997).

GENE MARKERS FOR MEAT QUALITY TRAITS HAVE BEEN IDENTIFIED

Our research on gene markers for carcass and meat quality traits is using a number of experimental herds. The most important herd comprises progeny from three Charolais x Brahman first cross bulls. The two parental breeds were chosen because they differ genetically for many growth, carcass and meat quality traits. Heifer and steer progeny are being grass finished to medium export specifications and slaughtered at live weights of 550 kg for steers and 520 kg for heifers.

Table 1. Effects associated with gene markers for a number of carcass and meat quality traits (Hetzel *et al*, 1997)

Trait	Herd mean	Average for marker type A_1	A_2	Gene marker effect (A_1-A_2)
Dressing percent	50.5%	49.8	51.3	1.5
Predicted carcass yield	196 kg	192	200	8
Marbling	1.2 units	1.1	1.5	0.4
Shear force	5.8 kg	5.6	6.0	0.4

Interim results from the study are presented in detail elsewhere (Hetzel *et al*, 1997). Between one and five gene markers have now been identified for each of the key carcass and meat quality traits. The size of effect associated with each gene marker varies. Some of the gene markers with larger effects are shown in Table 1. For example, animals differed for dressing percent by 1.5%, depending on what form of the gene marker (A_1 or A_2) was inherited from the sire. Similarly, different forms of a gene marker for marbling were associated with differences of 0.4 marbling score. Thus the individual gene marker effects can be quite large, and when combined with additional gene markers for these traits should have significant commercial value.

At this time, the gene markers are unproven in the sense that they have not been field tested in industry relevant breeds/crosses. Such testing is essential because the size of effects associated with each gene marker may vary between breeds, between herds or sire lines or between environments. Indeed, some gene markers may only be useful in certain breeds or sire lines. Thus evaluation of markers in industry herds must be undertaken. As a first step, gene markers are being tested in the breeds involved in the core breeding program of the Beef and Cattle Industries CRC. Seven breeds, viz. Angus, Murray Grey, Hereford, Shorthorn, Brahman, Santa Gertrudis and Belmont Red are represented. In addition, comprehensive evaluations of markers in individual herds are planned.

GENE MARKERS WILL MOST OFTEN BE USED IN COMBINATION WITH OTHER PERFORMANCE DATA

Most commercially important traits in beef cattle are affected by a number of genes which will range in the size of their effects. For instance, gene variants may vary from having small effects and be very common through to having very large effects but be relatively rare. Current genetic evaluation technologies assume that a large number of genes, with small but additive effects, contribute to the genetic variation that is observed in these traits. However, the use of gene marker technology will allow the moderate to large genes to be targeted individually. Thus for traits which are difficult to measure and hence difficult to breed for, direct selection will be possible with gene markers.

For example, evaluation of breeding animals for marbling is an expensive process requiring progeny testing and/or the use of scanning technology on breeding stock. However, if gene markers can be identified which account for a significant proportion of the variation in marbling score in feedlot finished steers, then selection of breeding stock could be made on juvenile animals with a reduced need to progeny test. Indeed for all commercially important carcass traits including those which will become determinants of price in the future such as meat tenderness and colour, gene markers may potentially contribute much of the information used to select breeding stock.

Nevertheless, since gene markers will in most cases tag only the major genes responsible for variation in a trait, it will make sense to use other sources of information to assess an animal's genetic merit. Thus sources such as the relative performance of an animal's relatives (or where available of the animal itself) can be used. In the future, genetic evaluation systems such as BREEDPLAN will be modified to include the use of gene markers to estimate breeding values (EBV). Only in special cases or for simple genetic traits will it be sensible to select on gene markers alone.

HOW WILL BREEDERS GAIN ACCESS TO AND/OR USE GENE MARKER TECHNOLOGY?

As described above, gene markers will be used to predict the breeding value of an animal for any particular trait. 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 as an extra piece of technology which 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.

In the future, only a small number of commercial laboratories in Australia will carry out gene marker tests on samples submitted by breeders. Test results will be returned to breeders either directly and/or via a genetic evaluation service such as BREEDPLAN. It is envisaged that breeders will access gene marker technology in three main ways.

(i) Buy breeding stock which have been 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.

Best use of gene markers will be achieved by firstly evaluating them within a breeder's herd (Figure 2a). In this way, the best gene markers can be chosen for ongoing use and the gene marker effects will be estimated in the relevant genetic background. However, the evaluation of gene markers is not a trivial exercise. Given the likelihood that optimum gene marker profiles will vary between family lines, there is a need to evaluate each sire line. Ideally 100 progeny from each sire (or grandsire) will be assessed for performance eg carcass and meat quality and tested for all available gene markers. The evaluation could be carried out on steer and heifer progeny. In this way, the optimum combination of gene marker types ie a gene marker profile, for a particular breeding goal, can be determined for each sire line. Sons can then be selected on the basis of their gene marker profiles as well as any other performance data which is relevant to the defined breeding objective.

Once profiles are established for a particular sire line, ongoing evaluation of gene markers is not required ie subsequent offspring (sons or daughters) can be ranked on their breeding values calculated from their profiles and any other performance information. As in most breeding programs, the breeder will likely use the best son for ongoing breeding, sell other sons with defined marker profiles as well as supply commercial herds (Figure 2b). Where linked markers are used, breeders will need to reevaluate the gene markers from time to time.

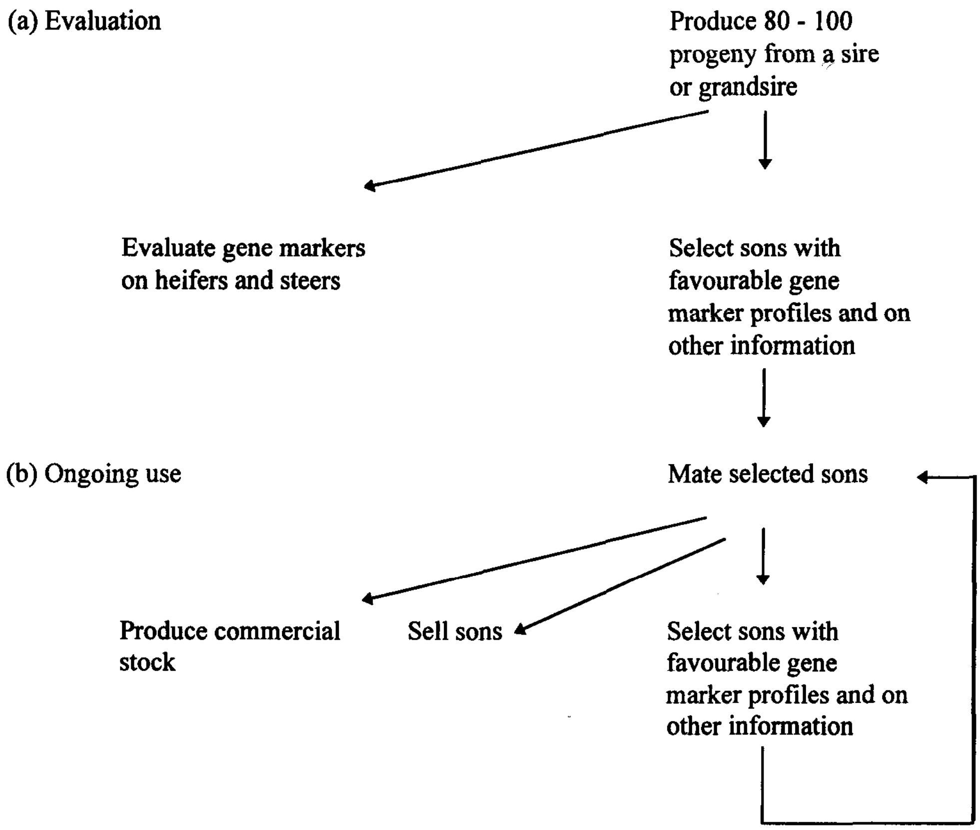

Figure 2. Evaluation of gene markers (a) and use in an ongoing breeding program (b).

(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 (Figure 2b). 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.

WHAT DOES THE FUTURE HOLD?

Gene marker technology is still in its infancy. However, evidence to date suggests gene markers will be a powerful breeding tool especially for traits which are difficult or expensive to measure such as carcass/meat quality, disease resistance and feed conversion efficiency. Current technology is based on linked markers and requires an evaluation phase prior to use of gene markers in breeding programs. Over the longer term eg 10-20 years, many gene markers based on the actual gene variants should be developed. Such markers, can be used without knowledge of an animal's pedigree and will make the technology simpler to use for all breeders as well as making it applicable to finishers/feedlotters.

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