Improving marbling by genetics

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Introduction

Marble score, as an indicator of intramuscular fat, has attracted a great deal of publicity and interest in recent years. While the role of marbling in the eating quality of beef is not yet fully understood it is accepted that marbling contributes favourably to the flavour and juiciness of beef with a limited effect on tenderness. Marbling is also important in the classification of carcases for some very profitable export markets and the restaurant sector of our domestic market. The USA and Japanese grading schemes place emphasis on marbling because the grades represented by higher marbling in both countries attract higher prices per kilo based on demand. Meat Standards Australia (MSA) includes marble score as one of the input variables in their prediction model of palatability. Higher marble scores result in higher MSA palatability scores. Therefore the deposition of fat in the muscle of beef carcases has an economic value in several markets. The challenge for the Australian beef industry is to determine how to produce carcases with the required level of marbling. Manipulation of the environment (eg feedlot finishing) and improved genetics are strategies that can be used together to improve marbling.

Some background

The relationship between visual marble score and intramuscular fat percentage is not absolute. A figure of 70% relationship is about normal. Both marble score and intramuscular fat percentage are heritable (between 28 and 40%) however the method used to measure or score marbling affects the heritability and therefore determines the usefulness of the measure in a genetic evaluation system. Factors other than genetics influence marbling. These include pre and post-slaughter management, age, weight, nutrition and time on feed. Since the costs associated with achieving marbling by management are recurrent, while genetic gains where obtained can be permanent, many producers are seeking sires whose progeny marble. This can be achieved by changing to a higher marbling breed, crossbreeding, or choosing superior sires within a breed. Also, recent advances in molecular genetics suggests some genes of large effect influence marbling. The GeneSTAR marbling test for one of the genes controlling marbling has now been on the market for over 18 months and the Beef CRC has been investigating additional marbling markers.

Breeds

Considerable breed differences exist for marble score. Some breeds have higher mean marble scores than others. The large differences can be used when selecting a breed to use in a straightbred operation or in a crossbreeding program. However the actual differences obtained for marbling will depend on the genetics, your environment, management and market weight. Although breeds differ in their mean marbling level, considerable variation exists between sires within all breeds. Even within the higher marbling breeds some sires have relatively poor marbling progeny.

Some that are higher:	Some that are lower:
Wagyu, Jersey,	Limousin
Angus, Murray Grey	Chianina
Shorthorn, South Devon	Brahman

Within Breeds

Variation exists within breeds for marbling. If we can identify those animals with superior marbling then it will be possible for seedstock herds to change marbling within a breed. These same animals could also be used in commercial production. BREEDPLAN now includes an estimated breeding value (EBV) for intramuscular fat called the IMF% EBV. This recent development is very important as it allows breeders to improve marbling by selection. The IMF% EBVs are calculated using records from live animal ultrasound scanning of intramuscular fat and abattoir carcase data. Abattoir data includes intramuscular fat records from the CRC (measured in a laboratory by chemically extracting the fat from a meat sample) and MSA marble scores from industry progeny tests. In addition to the scan and abattoir data, the IMF% EBV also incorporates marbling EPDs from overseas genetic evaluations.

Live animal scanning. Research in Australia and overseas showed that it is possible to measure marbling using real-time ultrasound scanning of yearling bulls and heifers. Australian research was conducted using several thousand animals scanned in seedstock Angus, Hereford and Santa Gertrudis herds. The heritability estimate for intramuscular fat % is moderate in heifers (25%) but lower in bulls (15%). Similar work has been done in the US and their heritability estimate for intramuscular fat in yearling bulls was 37%. The different heritability estimates are likely due to the US bulls generally being fatter at the time of scanning compared to Australian yearling bulls. Another important finding (now confirmed in both countries), critical to improving the trait, was that intramuscular fat measured by scanning in seedstock is positively genetically related to intramuscular fat expressed in finished steers.

The ability to use ultrasound data in a genetic evaluation program is important because it is cheaper than obtaining abattoir carcase data, it reduces the time lag in obtaining data, and should allow greater selection pressure (greater number of individuals in the population measured).

This is now evident with the large (tens of thousands) number of animals on breed society databases with scanned intramuscular fat records. However ultrasound data has a lower heritability than intramuscular fat (measured chemically) and therefore will require more data to achieve the same level of accuracy. Research to date shows that scanning for marbling will be sufficient for determining genetic differences between sires but it is not very accurate for an individual. Improvement in scanning technology continues and this will lead to increased accuracy. For data to be eligible to enter BREEDPLAN the ultrasound scanner must have passed a proficiency test for IMF% in the last three years (a full list of ultrasound scanners is available at http://agbu.une.edu.au).

CRC Abattoir Carcase Data

The Beef CRC has collected chemically extracted intramuscular fat records on over 7500 carcases. This data has been used in conjunction with ultrasound data from breed society databases to develop the new carcase module in BREEDPLAN. The CRC has also provided extremely important data on retail beef yield (RBY%). The data has allowed the genetic relationships between carcase traits and between carcase traits and other traits (e.g. scans, growth) to be estimated. For example, an important genetic relationship is that between IMF% and RBY%. Research show that at a 300 kg carcase weight the relationship is slightly negative (more details next page). That is, selection for increased IMF% is likely to lead to reduced RBY%. However with EBVs available for both traits it will be possible to find sires that can improve both traits.

The intramuscular fat % records from the CRC have been included in each of the cooperating breed society databases and have been used in their latest BREEDPLAN runs. Chiller assessed marble scores using the MSA system (0.2 score gradations per Aus-Meat score) are also used in the calculation of BREEDPLAN IMF% EBVs.

CRC Results

Analyses from the CRC Straightbreeding Project for all the carcase traits are now complete. The final database includes 7,500 animals with intramuscular fat % (IMF%) records. This is a very powerful set of data and is being used to further understand the genetics of marbling. Listed below is a brief summary of some of the most important genetic and non-genetic results (a full description can be found in Johnston 2001).

Non-genetic results:

- Heavier carcases (Japanese finished) had more IMF % compared to lighter carcase weights (Domestic weights).
- Grain finished cattle had higher IMF % compared to pasture finished.
- Heifers tended to have more IMF% than steers at the same market weight.

Genetic results:

- heritability of IMF% in both temperate and tropically adapted breeds is 0.38.
- the genetic variance of IMF% in temperate breeds is twice as much as the tropically adapted breeds.
- IMF% is negatively genetically correlated (-0.40) with retail beef yield%.
- IMF% is positively genetically correlated (0.2-0.3) with carcase fat depth.
- IMF% is very highly positively genetically correlated with marble score
- IMF% is positively genetically correlated with eating quality traits

Effect of Market on genetic expression:

- greater genetic expression of IMF% at Export weight carcases compared to Domestic.
- very high genetic correlation for IMF% between markets (0.92-1.0).

Effect of Finishing system on genetic expression:

- greater genetic expression of IMF% for grain finished compared to pasture finished carcases.
- very high genetic correlation for IMF% between grain and pasture finishing (0.96-1.0).

Effect of Region on genetic expression (Tropically adapted breeds only)

- very high genetic correlation for IMF% between cattle finished in temperate versus subtropical regions (0.94)

IMF% is heritable and variation exists (in both temperate and tropically adapted breeds) and therefore can be changed (up or down) by selection. Selection for IMF% will result in correlated changes to Aus-Meat marble scores. However IMF% is genetically related to other traits and if ignored in the selection process will result in correlated changes in these other traits. If this is not desirable then it is important that the selection decision is based on information on all traits affecting profit. The selection decision will need to be based on a combination of all these traits, where the emphasis on any one trait is determined by its economic value and its relationship with other profit traits. For a detailed discussion on valuing marbling in Australian beef breeding objectives see Barwick and Henzell (1999). In summary, their work showed that the economic value of improved marbling changed with the mean marble score of a herd and with the production/market system considered. For example, in a self replacing herd supplying the long-fed B3 Japanese market, marble score had the highest relative economic value of all the traits affecting profit.

The genes controlling the expression of IMF% under different production systems appear to be very similar. This has several ramifications. From a genetic evaluation viewpoint, data on IMF% from cattle from different weights or production systems are all measures of the same trait and could be used to estimate breeding values for IMF%. From a commercial industry perspective, animals selected under predominantly pasture based systems (ie. the seedstock sector) can be used to predict differences in the progenies performance when grain finished. Following this, a bull selected for his genetic superiority for IMF compared to another sire, is expected to express that benefit in his progeny irrespective of market weight endpoint, grain or pasture finishing and for the tropically adapted breeds, whether finishing is in a sub-tropical or a temperate environment.

Interpreting BREEDPLAN IMF% EBVs

Carcase EBVs are interpreted like all EBVs: they are differences not absolutes. The carcase EBVs in BREEDPLAN are adjusted to a standard 300kg carcase weight endpoint. Previously, carcase EBVs (from ultrasound data only) were adjusted to a constant age of 450 days. The change to the standard 300kg carcase endpoint for each of the carcase EBVs is designed to better reflect differences between sires for carcase traits at commercial endpoint and to allow for the inclusion of data from abattoirs on steers and heifers.

Important note: a negative EBV for IMF% does not mean "no marbling", it simply reflects the relativity of that animal's EBV to the mean of the breed. For the new carcase EBVs the mean EBV is around zero for most breeds. Therefore about half the animals in the breed will have an EBV below and half above zero. If the breed makes genetics progress, then over time, the mean will move away from zero.

The table below shows VDAR New Trend 315 with an IMF% EBV of +1.8 and GT Maximum at 0.4. It is expected that the progeny of New Trend at a 300kg carcase would have more intramuscular fat than GT Max progeny of about 0.7% (i.e. half the difference in the EBVs when run under the same conditions). This is likely to be about a third of an AUS-MEAT marble score. Note: the other EBVs would predict that GT Max carcases would have more eye muscle (+1.8 cm2), be considerably leaner, and have a higher retail beef yield percentage (+1.1%) compared to New Trend carcases.

Major Genes for the Marbling

Australian researchers have been successful in identifying a gene associated with marble score in long fed (200 days) Angus, Shorthorn, and Wagyu cattle. The gene association was discovered and patented by Dr Bill Barendse and his team at CSIRO in Brisbane, Australia with financial support from Meat and Livestock Australia. Thyroglobulin (TG) is the molecular store for the thyroid hormones T3 and T4. These hormones affect fat cell growth and differentiation. T3 and T4 levels have recently been associated with intra-muscular fat in Wagyu cattle by researchers in Canada. However the biological mechanism by which forms of the TG gene influence either marbling score or availability of T3 and T4 and thus marbling score is not known. GeneSTAR Marbling is a DNA diagnostic test for the TG gene sold by Genetic Solutions Pty Ltd, a Brisbane, Australia based livestock genetics company. The test has been available for more than 12 months and has been used by breeders in the United States, Japan, Canada, Argentina and Australia. Further details are available at the following web site www.genestar.com.au.

The test can be used to increase the frequency of the gene in seedstock herds but at this stage the test in not suitable for drafting purposes at a feedlot. The value of this gene depends on the frequency of the 2 star form in your breed. Results to date show that long fed cattle (Angus, Shorthorn and Wagyu) carrying 2 copies of the gene (2 star GeneSTAR marbling test) had twice as many Aus-Meat marble scores 4 and 5 compared to 0 or 1 star animals. New results are also emerging from US trials.

The GeneSTAR marbling status of animals can be used now by beef producers when making selection/ purchasing decisions (see the GeneSTAR web site for their recommendations). However the information will more useful to a selection program when combined with other genetic information (EBVs and indexes). Research is currently under way on assessing the best way of incorporating genotypic data into a genetic evaluation. Several factors need to be determined for a marker to be included: the proportion of variation the marker explains of an existing BREEDPLAN trait, the relationship between the marker and other traits, the expected level of recording in a population, the gene action of the marker, and others. Collaborative research is under way addressing these issues (for the inclusion of any marker) and should be well advanced by the end of the year. However in the short term, strategies are now being developed for the specific use of the GeneSTAR Marbling results. Pivotal to these developments, and their subsequent implementation, will be the accumulation of molecular data onto breed databases.

Table 1. January 2002 Angus GROUP BREEDPLAN EBVs

	400d kg	Cwt kg	EMA cm^2	P8 fat mm	RBY%	IMF %
VDAR NEW TREND 315	+64	+31	+1.4	+1.2	-0.2	+1.8
GT Maximum	+96	+71	+5.0	-3.2	+1.9	+0.4
2000 born EBV average	+51	+32	+1.1	-0.2	+0.2	+0.3