Selecting for marbling and its relationship with other important economic traits. What impact does it have?

David Johnston

Animal Genetics and Breeding Unit*, University of New England, Armidale, NSW

Phone: 02 6773 2658; Email: djohnsto@metz.une.edu.au

* *AGBU is a joint institute of NSW Agriculture and The University of New England*

Abstract. Genetic correlations between intramuscular fat % (IMF) and several important live animal, carcass, meat quality and eating quality traits were estimated using records on 3594 temperate and 3831 tropically adapted cattle. Animals were finished to three different market weight end-points, either on pasture or in a feedlot, and in different regions for the tropically adapted breeds. Phenotypic and genetic expression of IMF were examined at the different levels of market and finishing regime. Results showed IMF increased with increasing market weight. Feedlot finishing increased IMF compared to pasture finishing. Heifers (at the same market weight) had more IMF than steers. Tropically adapted breeds finished in Nth NSW had more IMF than those finished in sub-tropical feedlot. The heritability of IMF was 0.38 and 0.39 for temperate and tropically adapted breeds, respectively. However the additive variance of IMF was more than twice as much for temperate breeds compared to tropically adapted breeds. IMF was positively correlated genetically with measures of fatness and negatively with retail beef yield percent. The genetic correlations between IMF and growth traits were low, and moderate with meat quality traits. Genetic correlations with MSA eating quality traits (sub-set of data) were positive. Little evidence existed for genotype by market or genotype by finishing regime interactions for IMF. Genetic improvement of IMF is possible in both temperate and tropically adapted breeds, however some important genetic correlations will need to be addressed in any selection program.

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 still yet to be fully understood, it is generally accepted that marbling contributes to the flavour and juiciness of beef with a limited effect on tenderness. Marbling is also important in the classification of carcasses 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 results in higher MSA palatability scores. Therefore the deposition of fat in the muscle of beef carcasses has an economic value in several markets. The challenge for the Australian beef industry is to determine how to produce carcasses with the required level of marbling. Manipulation of the environment (eg. feedlot finishing) is one strategy, improved genetics is another. The purpose of this paper is to outline the extensive results from the CRC for Cattle and Beef Quality on the chemical measure of marbling called intramuscular fat (IMF) and the implications for genetic selection within breeds for improved marbling in the Australian beef industry.

CRC - Straightbreeding Design

i) The cattle

Cattle were from the straightbreeding project of the CRC for Cattle and Beef Quality; (See Robinson (1995) for the design of the project and Upton *et al.* (2001) for complete description of management and operations). In brief, the project was a large progeny test for carcass and meat quality traits from four temperate breeds (Angus, Hereford, Shorthorn, Murray Grey) and three tropically adapted breeds (Brahman, Belmont Red and Santa Gertrudis). All sires were performance recorded through BREEDPLAN and within a breed, genetic linkages across herds and year were generated through the use of common link sires.

Progeny were born during the years 1993 to 1998 in 34 cooperator herds throughout Eastern Australia. Parentage and date of birth were recorded on all animals on the cooperator herds and at weaning the animals were delivered to CRC managed properties in central Queensland and north-eastern New South Wales (see Bindon 200; Upton *et al.* 2001).

ii) Treatments

Animals were allocated to one of six finishing treatment groups for temperate breeds and nine for tropically adapted breeds. Allocation was based on the design of Robinson

(1995). In particular, sire progenies were balanced across treatments. Finishing treatments for temperate breeds were to three target market weights (domestic, Korean, Japanese) and market was cross-classified with finishing regime of pasture or feedlot. These target market weights were selected as they are indicative of the Australian domestic (220 kg) and export Korean (280 kg) and Japanese (340 kg) markets, respectively. For tropically adapted breeds, allocations were to the same three market weights (domestic, Korean, Japanese) with three cross-classified finishing regimes. The first two levels were animals grown out in the sub-tropics of central Queensland and finished either on pasture (pasture-north) or feedlot (feedlot-north). The third treatment, representing approximately one third of the tropically adapted animals, were relocated at weaning from central Queensland to northern-eastern NSW for grow-out and feedlot finishing (feedlot-south). The relocation of cattle was done to generate a region effect. The original design included a fourth level for pasture south, however only one cohort (n=72) was allocated to this treatment before low numbers forced this to be dropped from the design. A complete description of the design is presented in Upton *et al.* (2001).

The cattle were grown-out from weaning until they reached the required transfer to finishing live weight. Transfer occurred at an average live weight of 300 kg for domestic weight groups and 400 kg mean live weight for the Korean and Japanese market weight groups. Finishing was either feedlot or pasture. Slaughter occurred when the average weight of the cohort group reached the assigned market weight. Cattle were handled pre-slaughter using best industry practice and slaughtered at commercial abattoirs. Every effort was made to control the slaughter procedure to minimise extraneous variation, particularly for tenderness traits. This was essentially achieved through the application of electrical stimulation equipment, either with low voltage within five minutes post-slaughter, or high voltage 30-60 minutes post-slaughter. Twenty to twenty-four hours post-mortem, a 15 cm section of the *M. longissimus thoracis et lumborum muscle* (LTL) caudal from the 12/13th ribs was removed and used for determination of intramuscular fat. For a complete description of pre- and post- slaughter procedures see Perry *et al.* (2001). Consumer assessment of the palatability of the LTL sample was performed by Meat Standards Australia on a subset of the CRC animals (those killed after June 1998). Scores and protocols are described in Polkinghorne *et al.* (1999).

iii) Statistical analyses

For a complete description of the statistical analyses refer to Reverter *et al.* (2001a,b) and Johnston *et al.* (2001a,b). In brief, for the genetic analyses, traits were analysed using models that accounted for the design variables, such as herd of origin, sex, market and finish. For live animal traits (and carcass weight) the models also included a linear covariable to adjust for differences within a group for age of the animal at measurement. For abattoir and meat quality traits, the models included a covariable for carcass weight. Therefore the genetic estimates for the carcass and meat quality traits, including IMF, are expressed at a weight constant basis. The number of sires with progeny with IMF records were 232 and 163 for temperate and tropically adapted breeds, respectively.

Results and discussion

i) Trait means

The average level of IMF for temperate and tropically adapted breeds by market, finish (and sex and region for tropically adapted only) are presented in Tables 1 and 2.

Table 1. Means by market and finish for temperate breeds.

Effect	Level	Number records	IMF (%)	Carcase weight (kg)	Slaughter age (months)
Market	domestic	1253	3.3	205	16.6
	Korean	1236	5.1	280	22.8
	Japanese	1105	6.1	320	24.5
Finishing	Feedlot	1889	5.3	269	19.5
	Pasture	1705	4.0	252	22.3

Table 2. Means by market and finish for tropically breeds.

Effect	Level	Number records	IMF (%)	Carcase weight (kg)	Slaughter age (months)
Market	domestic	1468	2.2	216	20.5
	Korean	1643	3.0	274	27.1
	Japanese	720	3.5	320	30.0
Finishing	Feedlot-south	1298	3.5	257	22.2
	Feedlot-north	1259	2.6	263	23.0
	Pasture-north	1274	2.1	260	30.1
Sex	Heifer	1695	2.9	236	24.2
	Steer	2136	2.2	253	23.3

In brief, IMF increased with increasing market weight (and age). Feedlot finishing increased IMF compared to pasture finishing. Heifers (at the same market weight) had more IMF than steers. Tropically adapted breeds finished in Nth NSW (feedlot-south) had more IMF than those finished in sub-tropical feedlot (feedlot-north).

ii) Heritabilities

The data were analysed to estimate genetic parameters separately for the temperate and tropically adapted breeds. The heritability of IMF for was 0.38 and 0.39 for temperate and tropically adapted breeds, respectively. However the additive variance of IMF was more than twice as much for temperate breeds compared to tropically adapted breeds. Therefore we would expected greater genetic progress in temperate breeds compared to the tropically adapted breeds. Given these population estimates it could be expected under single trait selection that IMF could be increased at a rate of between 0.5 to 1.0% per generation in temperate breeds and 0.3 to 0.7 % per generation in tropically adapted breeds (depending on the selection intensity and the accuracy of selection).

iii) Genetic correlations

Estimates of the genetic correlations between IMF and other important traits are presented in Table 3. There is a high degree of consistency in the direction and magnitude of the correlations between IMF and the other traits for temperate and tropically adapted breeds. In general, IMF was moderately positively correlated genetically with carcass fatness (+0.2 to +0.4) but negatively correlated with retail beef yield % (-0.4). If from the previous example IMF was increased at a rate of 1% per generation, then we would expect that retail beef yield % would *decrease* at about 0.6% per generation in the population. However this is unlikely to occur if breeders also make selection decisions using the estimated breeding value (EBV) for retail beef yield %. That is, if both traits are measured in a breed then it will be possible to identify sires (and cows) that will improve both traits.

Genetic correlations with weight traits were low and mostly slightly negative. However estimates with measures of feed intake and net (residual) feed intake were moderate and positive, suggesting a slightly unfavourable genetic relationship between IMF and feed efficiency.

Genetic correlations between IMF and meat quality traits were low to moderate and generally favourable in direction. For tropically adapted breeds IMF was correlated 0.39 with L-value meat colour, indicating increasing IMF would result in genetically brighter meat (higher L-values are brighter). IMF was genetically highly correlated with Ausmeat marble scores (0.96 for temperate breeds and 0.89 for tropically adapted breeds), indicating they are measures of the same trait but with different heritabilities being the result of different

Table 3. Genetic correlations between IMF and other traits for temperate and tropically adapted breeds.

Trait group	trait	temperate breeds	tropically adapted breeds
Live animal measures[a]	scan p8 fat	0.39	0.22
	scan eye muscle area	-0.17	-0.59
	live weight	0.09	-0.22
	daily feed intake	0.19[b]	
	net feed intake	0.21[b]	
Abattoir carcass	Carcass weight	-0.12	-0.03
	retail beef yield %	-0.38	-0.43
	P8 fat depth	0.34	0.22
	12/13[th] rib fat depth	0.21	0.20
	Ausmeat marble score	0.96	0.89
Meat quality	meat colour (L-value)	-0.16	0.39
	cooking loss %	-0.14	-0.17
	shear force – strip loin	-0.34	-0.10
	shear force - eye round	-0.33	-0.32
Eating quality[c]	MSA – flavour score	0.75	0.43
	MSA – juiciness score	0.69	0.54
	MSA- tenderness score	0.73	0.29
	MSA- MQ4 score	0.70	0.37
	MSA – marble score	1.0	0.94

[b] estimates from an analysis pooled across the temperate and tropically adapted breeds

[c] only a sub-set of animals had MSA scores; N=1,152 for temperate breeds and N=1,585 for tropically adapted breeds

measurement techniques. The genetic correlations with MSA eating quality traits are based on only a sub-set of the data and estimates must therefore be considered with caution. In general, the correlations were positive and moderate to strong, suggesting a favourable relationship genetically between IMF and eating quality attributes.

iv) Genotype by environment interactions

To investigate the effect of market weight (domestic versus export) and finishing system (grain versus pasture) on the genetic expression of IMF the effects were considered as different traits in a genetic analysis. For tropically adapted breeds, finishing region (feedlot north and feedlot south) were also considered as two separate traits. These analyses allowed the magnitude of the genetic expression of IMF at each level to be estimated as well as the genetic correlations between grain and pasture finishing; and between domestic and export weights. For tropically adapted breeds the difference in genetic expression and genetic correlation between regions was examined.

Results (Tables 4 and 5) show market weight increased the genetic expression of IMF considerably but the genetic correlation between markets was very high (0.92 and 1.0 for temperate and tropically adapted breeds, respectively). Similarly, grain finishing increased the genetic expression of IMF but again the correlations were very high (1.0 and 0.95 for temperate and tropically adapted breeds, respectively). Finally the effect of region for tropically adapted breeds

Table 4. Genetic correlations for IMF for market weight, finishing system for temperate breeds.

Trait Group	level	variable	
Market weight	domestic	additive variance	0.33
		heritability	*0.41*
	export[a]	additive variance	1.28
		heritability	*0.47*
		genetic correlation	**0.92**
Finishing regime	pasture - south	additive variance	0.46
		heritability	*0.30*
	feedlot - south	additive variance	1.22
		heritability	*0.49*
		genetic correlation	**1.0**

[a] the Korean and Japanese markets were pooled and called export

Table 5. Genetic correlations for IMF for market weight, finishing system (including region) for tropically adapted breeds.

Trait Group	level	variable	
Market weight	domestic	additive variance	0.21
		heritability	*0.39*
	export[a]	additive variance	0.47
		heritability	*0.38*
		genetic correlation	**1.0**
Finishing regime	feedlot - south	additive variance	0.49
		heritability	*0.42*
	feedlot - north	additive variance	0.47
		heritability	*0.46*
	pasture - north	additive variance	0.21
		heritability	*0.31*
		correlation feedlot - pasture	**0.95**
		correlation north - south	**0.94**

[a] the Korean and Japanese markets were pooled and called export

showed similar genetic expression with a high 0.94 correlation between regions. Therefore although the different market and finishing regimes changed the phenotypic and genetic expression of the trait we saw little or no evidence of re-ranking of sires on their progeny's performance across the different systems.

Selection for marbling

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 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, bulls selected for their 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.

Using marbling information

It is important that if you plan to improve marbling by genetics that you use the appropriate information. Due to the many environmental influences on marbling it is important that these are removed before making genetic decisions. This applies to both ultrasound scanned and abattoir IMF data. The IMF% EBV is the best method for comparing sires for expected differences in their progeny marbling. In general, abattoir data from groups of commercial cattle is not suitable for a BREEDPLAN analysis, unless the data is from a well designed progeny test.

IMF% EBVs will not tell you how much marbling the progeny of a sire will have, they only predict differences. The actual level will be determined by genetics but also other factors such as season, age, year, feedlot vs pasture, carcass weight, and processing conditions. However if you wish to improve marbling in your herd by genetics you first must determine where you are. This is often quite difficult, and firstly requires feedback on the marbling performance of your cattle from abattoirs. Next you need to genetically benchmark your current cow herd. To do this you will need to examine the breeds of sires used, and if available, the marbling EBVs of those sires. This information will give you an idea of the average marbling performance versus the average genetics for marbling of your herd.

Commercial producers must remember that half the genetics for marbling in the steer comes from his mother. Therefore your cow herd influences your marbling performance, as well as the bulls you use. If data from individual slaughter animals can be traced back to individual dams, you could affect change also by selecting females (according to the feeding and carcass performance of their calves) and improving the average marbling of your cow herd.

Producers need to select sires and dams for feedlot performance and carcass traits without losing sight of the other traits that make the cow herd profitable: adaptation, reproductive performance including calving ease, and growth and maternal traits. Try to **optimise** on a multi-trait basis. If you simply maximise one trait, you tend to end up penalising at least one of the others.

Take home messages

- marbling can be improve by genetics
- marbling is genetically related to other important traits
- selection for marbling should be done considering all traits that determine profit
- little evidence of GxE for marbling

Acknowledgements

The design, operation, data collection, analyses and interpretation of results in this study are the combined effort of a large number of scientists, technicians and cooperator breeders. In particular, the scientific contributions of Toni Reverter, Heather Burrow, Drewe Ferguson, Diana Perry, John Thompson, Hutton Oddy and Mike Goddard are recognised. The efforts of Elke Stephens and Andrew Blakely (and thier staff at Armidale) and Janet Stark (at Cannon Hill) in the processing of the IMF samples is gratefully acknowledged as are the contributions of numerous staff involved in the handling of the animals and collection of abattoir samples.

References

Barwick, S.A and Henzell A.L. (1999) Assessing the value of improving marbling in beef breeding objectives and selection. Aust. J. Agric. Res. 50:503-12.

Bindon, B. M. (2001) The CRC context: integration of resources for beef quality research 1993-2000. Aust. J. Exp. Ag. 41.

Johnston, D.J., Reverter, A., Burrow, H. M. and Oddy, V. H. (2001a) Genetic and phenotypic characterisation of live animal, carcass and meat quality traits from temperate and tropically adapted beef breeds. I Live animal measures. Aust. J. Exp. Agric. (in press).

Johnston, D.J., Reverter, A., Ferguson, D. M., Thompson, J.M. and Burrow, H. M. (2001b) Genetic and phenotypic characterisation of live animal, carcass and meat quality traits from temperate and tropically adapted beef breeds. III Meat quality traits. Aust. J. Exp. Agric. (in press).

Perry, D., Shorthose,W.R., Ferguson, D.M. and Thompson, J.M. (2001) Methods used in the CRC program for the determination of carcass yield and beef quality. Aust. J. Exp. Ag. 41.

Polkinghorne R., Watson, R., Porter, M., Gee, A., Scott, J. and Thompson, J. (1999) Meat Standards Australia, a 'PACCP' based beef grading scheme for consumers. 1) the use of consumer scores to set grade standards. In 'Proceedings of the 45th International Congress of Meat Science and Technology'. Yokohama, Japan. 45, 14-15. (ICoMST: Yokohama).

Reverter, A., Johnston, D.J., Burrow, H. M., Perry, D., Goddard, M. E. (2001a) Genetic and phenotypic characterisation of live animal, carcass and meat quality traits from temperate and tropically adapted beef breeds. II Abattoir carcass traits. Aust. J. Exp. Agric. (in press)

Reverter, A., Johnston, D.J., Burrow, H. M., Oddy, V.H., Perry, D., Ferguson, D. M., Thompson, J.M., Goddard, M.E. and Bindon, B.M. (2001b) Genetic and phenotypic characterisation of live animal, carcass and meat quality traits from temperate and tropically adapted beef breeds. IV Correlations among live animal, abattoir carcass and meat quality traits. Aust. J. Exp. Agric. (in press)

Robinson, D.L. (1995) Design of the CRC straightbreeding genetics experiments. Proc. Aust. Assoc. Anim. Breed. Genet. 11: 541.

Upton, W., Burrow, H.M., Dundon, A., Robinson, D.L. and Farrell, E.B. (2001) Cooperative Research Centre breeding program design, measurements and database - methods that underpin CRC research results. Aust. J. Exp. Ag. 41.