The genetics of carcase and beef quality: take-home messages from the Beef CRC

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Introduction

Australian beef breeders are faced with the challenge of using vastly diverse production environments and systems to produce cattle that are both productive and profitable and beef products that satisfy consumer requirements. To do this, they need knowledge of genetic and non-genetic influences on beef production and quality. Reviews of the literature in the early-mid 1990s indicated that many traits associated with body composition of cattle, including meat yield and fatness, are under genetic control. Such control provides an ability to manipulate beef quantity through genetic means. However at that time, there were very few reports relating to the genetic influences on eating quality of beef, particularly with respect to consistency of tenderness and palatability.

Genetic variation in both quantity and quality of beef is evident through differences between breeds and crossbreeds and between animals within a breed. Within-breed variation includes direct genetic effects as well as the correlated impacts of related traits on other economically important productive and adaptive traits that affect beef production. To address these issues, the Beef CRC developed an integrated research program to focus on the major production and processing factors affecting carcase and beef quality. Underpinning the CRCI program were two large-scale progeny testing programs used to develop quantitative and molecular genetic technologies to breed cattle better suited to new and existing markets and to design novel feeding, management and meat processing strategies to ensure eating quality of beef. In CRCII, a major breeding project (known as Project 2.3) was established to examine the possible trade-offs in reproduction and adaptation as a result of selection to improve carcase and beef quality attributes. This paper reviews the contributions made by the first two phases of the Beef CRC to identifying the quantitative genetic influences on beef quantity and quality and provides recommendations to Australian beef producers about the best methods of genetically manipulating the traits that affect properties of beef.

CRCI Straightbreeding Program

The CRC's straightbreeding program involved 7 breeds in which pedigreed calves were generated in 34 commercial herds throughout eastern Australia. The calves were purchased by the CRC at weaning and were managed through a complex research protocol that enabled scientists from multi-disciplinary teams to work together to identify genetic, nutritional, management and meat processing factors that affect beef quality. A full description of the CRCI straightbreeding and crossbreeding programs can be found in Upton et al. (2001). Breeds in the program were from biologically diverse types of cattle and from environmentally diverse properties of origin. Bos taurus breeds were four British breeds (Angus, Hereford, Murray Grey and Shorthorn) and the Sanga-derived Belmont Red breed. Large European Bos taurus breeds were not included because cow herds of sufficient size to generate the required numbers of progeny could not be located. The Brahman breed represented Bos indicus breeds. The Santa Gertrudis breed represented the Bos indicus x British stabilised breeds. Belmont Red, Brahman and Santa Gertrudis are all tropically adapted breeds. British cattle for the program were bred in temperate areas, whilst the tropically adapted cattle were bred in (sub) tropical areas of Australia.

All sires represented in the program were performance recorded through their respective breed society's Group BREEDPLAN to allow evaluation of sires relative to industry standards. Individual collaborating breeders and the breed societies selected sires for the program. Genetic linkages were generated between herds of the same breed by use of common ('link') sires in all herds through a combination of artificial insemination (AI) and natural joining. After weaning, calves were transferred to properties under the CRC's
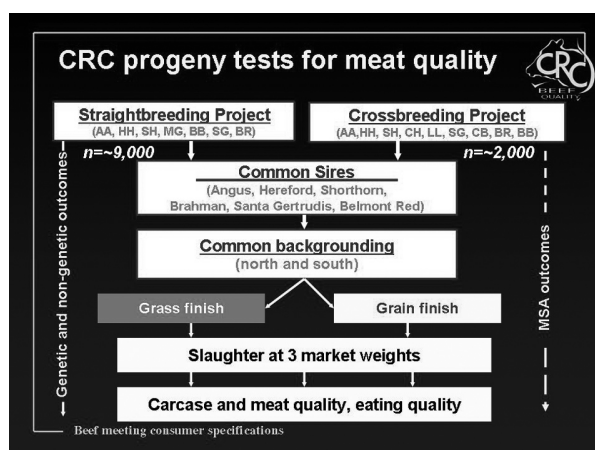
Figure 1. Design of CRCI breeding programs targeting meat quality traits (AA, Angus; HH, Hereford; MG, Murray Grey; SH, Shorthorn; BB, Brahman; SG, Santa Gertrudis; BR, Belmont Red; CH, Charolais; LL, Limousin; CB, Charbray)

Figure 2. Design of CRCI crossbreeding program targeting meat quality traits

control for growing and finishing to experimental specifications according to the CRC experimental protocol, which included allocation of sire progeny at weaning to pasture (i.e. grass) vs. grain finishing; domestic vs. Korean vs. Japanese market endpoints; and for the tropically adapted breeds, northern vs. southern growout and finishing. Calves were subsequently managed together within contemporary management or cohort groups.

CRCI Crossbreeding Program

Sire breeds in the CRCI crossbreeding program represented different biological types and included Bos indicus (Brahman-purebred control), Bos taurus-British (Angus, Hereford, Shorthorn), Bos taurus-European (Charolais and Limousin), Brahman x British-derived (Santa Gertrudis), Brahman x European-derived (Charbray) and Sanga-derived (Belmont Red). All sires except Charbray were performance recorded in their breed society's Group BREEDPLAN analysis. Charbray sires were F1 Charolais x Brahman, whose sires were recorded in the Charolais Group BREEDPLAN analysis and whose dams were recorded in the Brahman Group BREEDPLAN analysis.

About 1,000 Brahman cows that were donated to the CRC by northern Australian pastoral companies, individual beef producers and the Queensland Department of Primary Industries were joined at "Duckponds" and Brigalow Research Station over 3 joining periods to produce comparable pure-bred Brahman and Brahman crossbred calves that were weaned in 1996, 1997 and 1998 at an average age of 6 months.

To strengthen the experimental design, genetic linkages were generated between the CRC's crossbreeding and straightbreeding projects by use of common sires across projects. For breeds
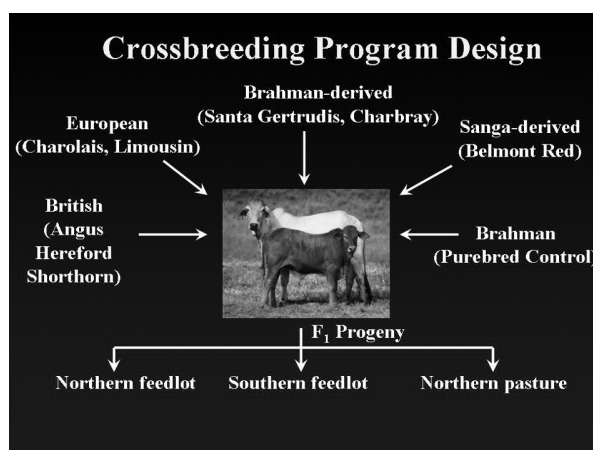
common to both programs (Angus, Belmont Red, Brahman, Hereford, Santa Gertrudis and Shorthorn), only sires that had been used in the straightbreeding program were used in the crossbreeding program. Most joinings within the crossbreeding program were by AI, followed by natural mating to 'back-up' sires of a different breed. A small number of sires were naturally mated at the same time as the AI programs to ensure calves by natural mating and AI sires were born at the same time. The aim of the program was to generate about 20 steer and heifer progeny (10 of each sex) per sire for each of the sires used in the crossbreeding program.

CRCII Project 2.3

A more complete description of the design of CRCII Project 2.3 is presented by Burrow et al. (2003) and Burrow and Bindon (2005). The aim of the project is to increase knowledge of genetic relationships between components of herd profitability in northern Australian environments at both quantitative and molecular genetics level, in order to improve efficiency and product quality without unduly compromising breeder herd performance or adaptability. The strategy was established to examine a pivotal issue in Australian beef cattle genetic improvement: 'Can we change carcase and beef quality attributes by selection without unduly compromising key fitness traits like reproductive performance and adaptation to harsh environmental stressors?' Industry outcomes from the project are targeting multiple traits and multi-faceted strategies for improving carcase and beef quality, feed efficiency, female fertility and adaptation to tropical environments, and use of tools such as estimated breeding values (EBVs), genetic (DNA based) markers, ultrasound scanning and meat processing (tenderstretch vs. achilles hanging) and cattle management strategies.

A specifically designed breeding program was implemented to generate the project's experimental

progeny. The main genetic relationships to be estimated are those among steer feed efficiency, carcase and meat quality attributes and female performance traits. Design aspects of the project include:

- Use of two tropically adapted breeds (Brahman and Belmont Red/tropically adapted composite), representing extremes of breed difference amongst tropically adapted breeds for carcase and beef quality, adaptation and male and female fertility traits;

- A target of 2,400 progeny per breed was the minimum to estimate genetic relationships within each breed, representing 20-30 progeny per sex for each of 40-50 sires per breed;

- Inclusion of sires for experimental design reasons as well as nomination of sires by collaborating breeders. Sires nominated by CRC were selected primarily on presence of accurate EBVs for retail beef yield % and intramuscular fat %. Secondary selection criteria included known heterozygosity for gene markers identified in CRCI, EBVs for scrotal size or days to calving and, in Brahman sires, whether they were prominent sires within the breed. Also considered was the ability of a sire to genetically link the project to other projects (e.g. CRCI straightbreeding and crossbreeding projects) and to industry data (e.g. Brahman BREEDPLAN herds). Most sires nominated by the collaborators were young, unproven bulls;

- Allocation of breeding animals to artificial inseminations, natural service joinings and management groupings to ensure genetic linkage of progeny across management groups, and as much balance as possible in the representation of sire progeny over linked groups. Environments for measuring heifer/cow performance traits were chosen to represent the range encountered by each breed, also recognising that the expected range for performance includes harsher (e.g. greater tick and worm prevalence) environments for Brahmans than for Belmont Red/tropically adapted composites.

The project is also targeting other key relationships that are potentially very important for genetic improvement programs and evaluation of management options, but which require new or additional data to quantify or confirm them. These include:

- Genetic relationships between plasma insulin-like growth factor (IGF1) concentration measured

at different stages of an animal's life and feed efficiency, carcass attributes and female fertility traits;

- A comparison of the effect of method of hanging carcasses (Tenderstretch vs. Achilles-hung) on carcass and beef quality and especially on genetic parameters for beef tenderness;

- Phenotypic and genetic relationships of flight time (a measure of temperament) and feed efficiency with carcass and beef quality attributes and female fertility traits;

- Complete economic analyses to examine the economic impact of changed genetics and/or management practices on herd profitability.

CRCI Straightbreeding Program: Results and Discussion

An essential component of the straightbreeding project was its strict design that allowed the estimation of genetic and non-genetic effects. This required careful allocation of sire progeny to treatment groups. Genetic parameters were estimated for a very large number of traits. Analyses were performed in blocks of traits: live animal, carcase traits and meat quality attributes. Live traits were also split and analysed at 3 stages (post-weaning, start of finishing and pre-slaughter). Genetic parameters included heritability estimates for all traits and genetic correlations between all traits in a block (and across treatments and stages for live animal traits).

Heritabilities range from 0-100% and indicated the extent to which a trait is under genetic control, with the higher the heritability, the greater the degree of genetic control. Genetic correlations range from -100 to +100% and indicate the extent to which common genes control two traits. A genetic correlation of 100% indicates that exactly the same genes control the two traits, whilst a 0% correlation indicates the two traits are completely independent. If a negative correlation exists, then an increase in the measurement of one trait results in a correlated decrease in the value of the other trait.

Table 1. Heritabilities (bold, on the diagonal) and genetic correlations (where ≥20%) between some traits for temperate breed animals (adapted from Reverter et al. 2003b)

	Trait	1	2	3	4	5	6	7	8	9	10	11	12
1	Weight (end of growout)	**50**		53	89	-20		-28					29
2	Scan P8 (end of growout)		**39**	20		-57	39	80		-23	-26	32	
3	Scan EMA (end of growout)			**33**	52					24			
4	Carcase weight				**39**			-39	-46	66	-20		-30
5	Retail beef yield %					**57**	-38	-48			24	-26	
6	Intramuscular fat %						**38**	34			-38	61	-32
7	Carcase P8 fat							**36**			-40	57	
8	Ausmeat meat colour								**11**	-29			58
9	Minolta meat colour									**17**	-23		
10	Striploin shear force										**9**	-49	58
11	MSA tenderness score											**18**	-42
12	Eye round shear force												**11**

Table 2. Heritabilities (bold, on the diagonal) and genetic correlations (where >20%) between some traits for tropically adapted animals (adapted from Johnston et al., 2003a,b; Reverter et al., 2003a,b).

	Trait	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Flight time (postweaning)	**29**										-48	37	
2	Weight (end of growout)		**30**	-42	29	82	20	-21	-22					
3	Scan P8 (end of growout)			**21**		-41		23	88					
4	Scan EMA (end of growout)				**22**	20		-58		39	-44		-29	34
5	Carcase weight					**36**				-55	60	-21		
6	Retail beef yield %						**50**	-43	-28					
7	Intramuscular fat %							**39**	22	-29	38		31	-31
8	Carcase P8 fat								**30**				21	
9	Ausmeat meat colour									**11**	-83	34	-41	
10	Minolta meat colour										**18**	-40	54	-29
11	Striploin shear force											**30**	-79	46
12	MSA tenderness score												**31**	-73
13	Eye round shear force													**42**

For several key traits (i.e. those that were heritable), genetic correlations were estimated between traits across blocks. All analyses were performed separately for temperate and tropically adapted breeds. Example heritabilities and genetic correlations for the same traits in temperate and tropically adapted breeds are shown in Tables 1 and 2 respectively.

Carcase composition traits (e.g. carcase weight, fat thickness and marbling) were all moderately to highly heritable. Estimates of retail beef yield percentage were highly heritable in both temperate and tropically adapted breeds, offering good potential for within-breed selection for the trait, although a moderate to strong antagonistic relationship exists between yield and marbling. This relationship needs to be considered in within-breed selection programs for yield percentage.

Early estimates of heritability of objective measures of beef tenderness (Warner Bratzler shear force values) from the scientific literature indicated tenderness was moderately to highly heritable. Analyses from the CRCI dataset, using larger numbers of carcases and more discriminatory methods of analysis, indicated that beef tenderness is lowly heritable in Bos taurus breeds and moderately heritable in Bos indicus and Bos indicus-derived breeds when meat processing factors are controlled. However, only moderate correlations between tenderness in different muscles suggest that genetic improvement in beef tenderness using direct selection methods is likely to be difficult.

Genetic correlations for all traits were also analysed as separate traits for pasture vs. grain; domestic vs. export markets (Japanese and Korean combined due to low numbers for genetic parameter estimation) and, for the tropically adapted breeds, for sub-tropical vs. temperate backgrounding, as shown for example in Table 3.

BREEDPLAN Estimated Breeding Values (EBVs) have been calculated on an ongoing basis since 1998 for all breeds in the Straightbreeding project. CRCI data contribute to growth and scanning EBVs but more importantly to carcase weight, carcase P8 and rib fats, eye muscle area, retail beef yield % and intramuscular fat % EBVs. More recently, flight time is being developed in BREEDPLAN as an indirect selection method to genetically improve beef tenderness (see following section).

The raft of genetic parameter and new knowledge on correlations between finish and market endpoints have been used to improve the genetics of carcase and meat quality traits, through improvements in BREEDPLAN as well as their incorporation into the breeding objective framework of BreedObject. The enhancements made possible by CRCI data and research to carcase and meat quality traits (in particular, retail beef yield and intramuscular fat %) have been a contributing factor in the development and publication of breed standard indexes for all breeds. CRCI results are also being used on an ongoing basis to advise breed societies, companies and individual breeders on the best methods to improve their breeding programs.

Simple indirect selection to improve beef tenderness

Results from CRCI straightbred analysis from tropically adapted breeds have identified a simple indirect criterion that breeders can use on-property

Table 3. Genetic correlations between pasture vs. grain finishing, domestic vs. export markets and northern vs. southern growout for chiller and meat quality attributes for temperate and tropically adapted breeds (adapted from Johnston et al., 2003a,b; Reverter et al., 2003a,b).

	Temperate		Tropically Adapted		
Attribute	Feedlot *vs.* Pasture	Domestic *vs.* Export	Feedlot *vs.* Pasture	Domestic *vs.* Export	North *vs.* South
Carcase weight	0.88	1.00	0.87	0.95	0.97
Intramuscular fat %	1.00	0.92	0.95	1.00	0.94
Compression (striploin)	1.00	1.00	1.00	0.73	1.00
Shear force (striploin)	0.72	1.00	1.00	0.89	0.92
Compression (eye round)	0.52	0.46	1.00	1.00	0.93
Shear force (eye round)	1.00	0.40	0.86	1.00	0.81
Cooking loss	0.68	0.87	0.67	1.00	0.79
Retail beef yield %	0.93	1.00	0.60	0.73	0.80
P8 fat depth	0.92	0.85	0.91	1.00	0.64
Meat colour	1.00	1.00	0.51	0.75	0.59
Fat colour	-0.09	-1.00	1.00	0.52	1.00
Marbling score	0.91	1.00	0.58	0.91	0.75

to select for beef tenderness and eating quality. Significant favourable genetic relationships between flight time, an electronic measurement of temperament, and beef tenderness and eating quality have been found in CRCI tropically adapted cattle breeds. Animals with poor temperaments, measured by fast (i.e. low) flight times, produce progeny with beef that is tough and of unacceptable eating quality. These relationships mean that flight time can now be used early in an animal's life to select breeding stock that will have better temperament and importantly, indirectly improve the eating quality of their progeny.

When designing cattle breeding programs, it is necessary to understand the relationships between different traits, because quite often, selection to improve one trait will lead to changes (favourable and unfavourable) in another trait if common genes control the different traits. This is why early-life weights can be used to improve carcase weights of cattle. Another example is the case of a negative relationship between retail beef yield percentage (RBY%) and intramuscular fat percentage (IMF%): selection to improve RBY% will generally decrease IMF% or marbling because of the negative genetic relationship between the two traits.

The genetic correlations between a single measure of flight time at weaning and shear force and MSA taste panel tenderness in ~4,000 tropically adapted steers and heifers in CRCI were -0.42 and +0.33 respectively (Kadel et al., 2006; note that low or fast flight times indicate poor temperament; low shear force values indicate tender meat; and high MSA tenderness scores indicate good eating quality and tenderness). Flight time is the CRC's measure of temperament, with fast (low) flight times indicating animals with poor temperaments. These results show strong favourable genetic relationships between beef tenderness (measured objectively by shear force values and subjectively by Meat Standards Australia (MSA) consumer taste panel tests) and MSA overall eating quality score. Genetic relationships between flight time and body composition traits such as yield and marbling are close to zero, indicating that the genes controlling temperament are not the same as those controlling yield and marbling.

Phenotypic relationships between flight time and carcase and beef quality attributes were close to zero in CRCI animals that had been slaughtered using "best-practice" processing. Evidence from CRCI data and the scientific literature suggests the best way to overcome problems of beef tenderness associated with poor temperament in the existing herd (i.e. at the phenotypic level) is to use best-practice processing.

CRCI Crossbreeding Program: Results and Discussion

No single cattle breed has all attributes that are needed to produce beef efficiently in all environments and to meet the requirements of all markets. Great variation exists between breeds in performance for both productive and adaptive traits. Hence, appropriate use of systematic crossbreeding programs provides significant benefits to beef producers, particularly through improved growth and female fertility, in both temperate and tropical environments. In the early 1990s (when CRCI was established), numerous reports were available on the effects of crossbreeding on carcase and beef quality attributes in Bos taurus breeds of cattle reared in temperate environments. Many of these reports also included tropically adapted breeds in their comparisons. However, there were few reports of breed and heterotic effects on carcase and beef quality attributes of tropically adapted cattle grazed at pasture in the tropics and subtropics. Hence, the CRCI crossbreeding program was established only in sub-tropical Australia.

Except for carcase weight, all CRCI crossbred carcase and meat quality attributes were adjusted to a common carcase weight. Carcase weight was adjusted for age at slaughter. All traits were adjusted for differences between sires within breeds by fitting sire as a random effect in the statistical model. Sire breed effects were important for all traits in the CRC's crossbreeding project. European crossbreds were significantly leaner than the tropically adapted crossbreds, which were significantly leaner than the British-sired crossbreds. Angus-sired progeny had the highest amount of subcutaneous fat cover, while Limousin-sired progeny were the leanest. Angus, Belmont Red and Shorthorn sires produced progeny with the highest intramuscular fat percentage (marbling). Brahman, Santa Gertrudis, Charolais and Limousin sired progeny had similar levels of marbling. Generally, breeds that had the greatest subcutaneous fat cover also had the highest amount of marbling. The exception was the Belmont Red-sired progeny, which scored intermediately for fat cover and high for marbling. European-sired progeny had the greatest retail beef yields. Purebred Brahman progeny had the toughest meat, whether measured objectively by shear force and instron compression measurements, or subjectively by untrained consumer taste panels. There was no major re-ranking of sire breeds or sexes across markets or finishing regimes for any weight or carcase attribute.

Based on CRCI results and evidence from the literature, genetic variation between breeds is of similar magnitude to genetic variation within breeds for most carcase and beef quality traits. Differences between breeds were significant and large for most carcase and beef quality attributes, including beef tenderness, although differences for sensory juiciness and flavour were of little practical importance. For traits such as beef tenderness, between-breed differences may be more easily exploited than within-breed differences, because

exceptional breeds are easier to identify than exceptional animals. Effects of heterosis on carcase and beef quality attributes are generally found to be relatively small (3% or less), with most effects mediated through heterotic effects on weight.

Take-home messages

General findings from the CRC's straight- and crossbreeding programs can be summarized as:

- Sire breed had large effects on growth and most carcase and beef quality attributes

- European sires had progeny with heaviest, leanest and highest yielding carcases

- Angus, Belmont Red and Shorthorn sires had progeny with highest intramuscular fat percentages

- Animals of high Bos indicus content fell below the MSA 3-star cut-off point

- Most crossbred carcases achieved MSA 3-star, with significant advantages to feedlot-finished crosses

- Pasture finished animals were significantly tougher than feedlot-finished animals, though there is also confounding with age (i.e. animals finished at pasture were generally older than grain-finished animals targeted for the same market)

- Heifers had consistently lower MQ4 scores than steers across markets and finish, with pasture-finished heifers not reaching MSA 3-star cut-off

- Contrary to expectations, meat toughness did not increase with increasing age or carcase weight to 3-3½ years or Japanese weight carcases

- Grain finishing increased IMF% relative to pasture finishing in the north; IMF% was highest in animals grain-finished in the south

- Progeny finished at pasture in the north were older, leaner, had highest retail yield percentages, greatest weight of retail primal cuts and consistently toughest meat

- No major re-ranking of sire breeds occurred across market (domestic, Korean, Japanese), finish (grain versus grass) or environment (north versus south) for carcase and beef quality attributes.

These results have serious implications for beef producers in northern Australia as they clearly show that, to achieve eating quality specifications, cattle breeds in these areas must not only be genetically able to meet market requirements but also need to be well adapted to environmental stressors. The CRC crossbreeding program provided significant input to the development of Meat Standards Australia, and particularly contributed results to support the inclusion of cattle with Brahman content in the MSA scheme.

Economic benefits of crossbreeding: Recent economic analyses showed that introducing Brahmans to British herds in northern Australia over 30 years provided a Net Present Value (NPV) of $8.1 billion (Farquharson et al., 2003). However, returns from infusing B. indicus into these herds slowed as herd composition stabilised on high-grade Brahmans. Use of crossbreds or tropically adapted composites offers further gains by improving product quantity and quality c.f. the Brahman, without compromising adaptation to environmental stressors. Additional economic evaluations were undertaken, at herd and northern Australian industry level, to examine the effect of changing 25% of the current 85% of Brahmans over 10 years to either a terminal crossbred or a tropically adapted composite based on a mix of B. indicus, Sanga and British.

These analyses compared grass- (Burrow et al., 2003a) and grain-fed (Griffith and Burrow, unpublished data) systems. In the grass-fed, individual-herd model, crossbreds and composites increased Gross Margins (GM) by $7 and $24 per adult equivalent (AE) cf. Brahmans. At the northern industry level, changing 25% of the herd over 10 years generated a NPV of $88m and $342m for crossbreds and composites respectively. As shown in Figure 3, in the grain-fed model, the extra GM of crossbreds and composites at individual herd level was $38 per AE for advantages in steer growth rate and feed efficiency, with extra GM of $5 and $9 per AE for advantages in marbling and tenderness respectively. Assumptions about the ability of crossbred and composite steers to achieve marbling and tenderness specifications were conservative. At northern industry level, benefits due to grain finishing translated to an extra NPV of $730m.
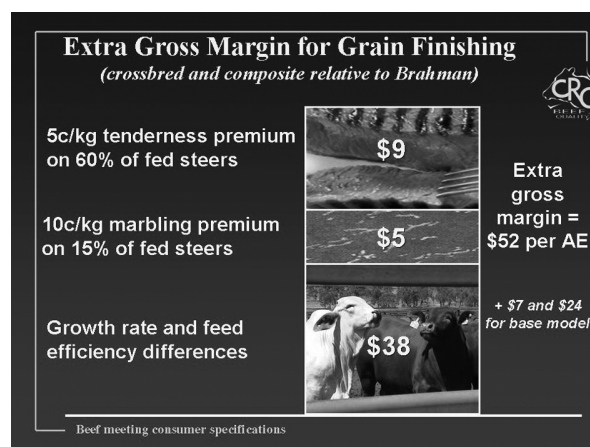

Figure 3. Significant economic advantages accrue to breeders of crossbred or tropically adapted composite animals (relative to Brahmans) bred in tropical areas and finished in feedlots to meet growth, feed efficiency, marbling and tenderness specifications.

Table 4. Preliminary estimates of additive variance (σA2), heritability (h2) and standard errors (SE) for carcase traits from Project 2.3 Brahman and Tropical Composite steers.

Trait	Units	n	σ_A^2	h^2	SE
Carcass Weight	kg	2160	547.12	0.59	0.09
Hot Carcass P8 Fat Depth	mm	2162	4.96	0.27	0.07
Cold Carcass P8 Fat Depth	mm	2067	5.34	0.37	0.08
MSA Eye Muscle Area (EMA)	cm²	2155	15.24	0.26	0.07
MSA Hump Height	mm	2087	148.7	0.23	0.06
MSA Ultimate pH	pH	2155	0.0004	0.06	0.04
MSA 12/13th Rib Fat Depth	mm	2087	2.08	0.20	0.06
MSA Ossification	score	2155	1734.35	0.46	0.08
MSA AUSMEAT Marbling	score	2155	0.063	0.34	0.08
MSA USDA Marbling	score	2154	1524.4	0.35	0.07
Chemically extracted IMF	%	2005	0.391	0.55	0.10
VIA Chiller Assessment (CAS) predicted IMF	score	1234	0.026	0.20	0.09
VIA CAS EMA	cm²	1234	37.55	0.40	0.10
VIA CAS predicted Carcass Yield	%	1234	0.537	0.43	0.10
VIA Whole Body System Predicted Carcass Yield	%	1580	0.579	0.34	0.09
Bone-out Carcass Wholesale Yield	%	554	2.91	0.48	0.16

CRCII Project 2.3: Results and Discussion

Preliminary carcase heritability estimates

Meat tenderness can be affected by cold shortening under conditions of rapid chilling relative to the rate of decline in muscle pH post-slaughter (Harris and Shorthose 1988). Application of processing techniques such as electrical stimulation, tenderstretching and correct aging of meat can be used to overcome the effects of cold shortening, but it is not known whether beef tenderness measured with or without correct application of processing techniques to overcome cold shortening is actually measurement for different attributes (and therefore whether selection to improve tenderness based on measurements of carcases that have been processed using/not using best practice will be effective). Johnston et al. (2001) reported that method of electrical stimulation had a large effect on the mean and variance of shear force values, particularly in the striploin in carcases that had been hung by the Achilles tendon. Non-stimulated slaughter groups were more variable than slaughter groups electrically stimulated with high voltage, which were in turn more variable than slaughter groups stimulated with extra low voltage. It is therefore possible that alternative methods of hanging of carcases such as tenderstretch (see Bouton et al. 1973)

may reduce the amount of variation in shear force values even further. Hence, one aspect of CRCII Project 2.3 was to examine genetic parameters in carcases from tropically adapted steers where one side of the carcase was hung by the achilles tendon and the other side was tenderstretched.

Data from this project are still being analysed. However, preliminary estimates of heritabilities from steers from the 2.3 project (pooled across Brahmans and Tropical Composites) are presented in Table 4 for the range of abattoir carcase traits, including Meat Standards Australia (MSA) and Video Image Analysis (VIA) measures. The number of records varied for the VIA and bone-out yield due to changes in abattoir and the non-recording (or loss of data) from some kill groups. In general the heritability estimates were moderate to high and similar to the previous CRC studies. All traits, with the exception of MSA pH, showed significant amounts of genetic variation and large differences between sires for their progeny performance. Research is currently underway to estimate the genetic (and phenotypic) correlations between the live steers traits and most importantly with their half-sib heifer reproductive performance traits.

Additional preliminary results shown in Table 5 clearly indicate significant benefits accrue from use of Tenderstretch. The benefits of tenderstretch were larger in poorer quality carcases and had the greatest effect on shear force (tenderness), with the greatest favourable effects seen in the toughest

Table 5. Least squares mean, additive genetic variances (σ2A) and heritabilities (h2) for carcase tenderness traits within Brahman and Tropical Composite steers (AT: achilles tendon; TS: tenderstretch; shear force: objective measure of myofibrillar (muscle) toughness with lower values indicating more tender beef; compression: objective measure of collagen toughness with lower values indicating more tender beef; cooking loss: amount of moisture loss during cooking, with higher values indicating greater propensity for moisture loss during cooking)

Breed / Trait	AT shear force (kg)	TS shear force (kg)	AT compress. (kg)	TS compress. (kg)	AT cook loss (%)	TS cook loss (%)
Brahmans	5.3	4.4	1.9	1.8	23.0	20.9
Composites	4.6	3.9	1.8	1.7	22.4	20.4
sed	0.1	0.1	0.02	0.03	0.3	0.2
Brahmans						
σ^2_A	0.37	0.08	0.01	0.01	0.48	0.24
h^2	0.33	0.30	0.20	0.15	0.09	0.07
Composites						
σ^2_A	0.35	0.07	0.01	0.01	1.07	0.72
h^2	0.32	0.30	0.20	0.27	0.23	0.21

carcases. Brahmans and Tropical Composites benefited equally from the use of Tenderstretch. Large sire differences for tenderness existed, but these differences were significantly reduced for shear force in carcases that had been tenderstretched.

Correlations between shear force measures in achilles-hung vs. tenderstretched carcases in Brahman, Tropical Composite and combined breed steers show the genetic correlations are significantly higher than the phenotypic correlations, indicating the relationships are strongest at the genetic level. They also indicate that selection to improve tenderness using measures of tenderness based on either achilles-hung or tenderstretched carcases will be equally effective, with only minor re-ranking of sires if the processing methods were to be altered.

Future developments

To improve the consistency of eating quality of beef, it is highly likely that multiple genetic and non-genetic strategies will be needed. Selection of breeds and animals within breeds using both quantitative and molecular genetic tools, nutritional strategies that optimize growth pathways, animal handling on farm and pre-slaughter, and post-mortem processing technologies all represent potential methods to improve eating quality of beef. In the medium term, the use of marker-assisted EBVs (based on a combination of traditional EBVs and use of DNA test results) is likely to assume greater importance in the Australian beef breeding industry. In the medium to longer term, a greatly enhanced biological understanding of the mode of action of major genes is likely to provide considerable extra value to beef producers. Knowledge of the mode of action of genes for particular attributes, and their associated effects on phenotype, is likely to lead to increased efficiency of animal production through both genetic and non-genetic means. For example, knowledge of the mode of action of genes may allow development of alternative management, pharmaceutical or nutritional regimes for animals to optimize production. As well, knowledge of the mode of inheritance of genes will allow better understanding of genetic correlations between traits.

A value-based marketing system that rewards beef producers, processors and retailers for implementation of such strategies will be the economic driver needed to guarantee the quality of Australian beef in future.

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