Factors influencing, and selection for, eating quality in Wagyu beef

This paper is a review of both genetic and nutritional technology that can be harnessed to improve eating quality of Wagyu beef and has been written in response to questions that have been fielded from the global Wagyu community. Genetic progress in Japan since the 1960s is reviewed. The reliance on imported feed for livestock in Japan is influencing Wagyu production so import data, pricing and consumption is presented. The principles that determine ultimate eating quality are reviewed so that production can be adapted in numerous marketplaces at a time that sustainability constraints are also impacting. Several fields are the subject of ongoing research so this topic is considered to be work in progress.

Elite Wagyu sale in Australia, May 2019

Records were smashed during the Australian 2019 Elite Wagyu National Sale held during the closing stages of the annual conference on 10th May 2019. Genetics on offer was required to be within the Top 5% of Wagyu genetics in Australia. An analysis has been made from Bids that were placed to identify the drivers that were behind buying decisions. Fullblood females peaked at a new Australian all-breeds female record price of $280,000, while embryos sold to a new national record of $10,200 each. Three females in the sale exceeded the previous Wagyu female record of $95,000 set at the auction in 2017. Some passed-in lots were negotiated after the sale, but the published results indicated that 15 of 17 Fullblood females offered had been sold, for an unprecedented average of $69,000. Within the bull offering, 13 of 23 lots were sold, averaging $26,577. The sale represented a truly international exchange of genetics, with vendors and buyers active from across Australia as well as South Africa, the United States, Wales, Canada and New Zealand.

Prior to 2016, sales at Elite Wagyu auctions were local but in that year a UK breeder chased high marbling semen to an unprecedented price of $3,050 per straw. This was followed by a South African in 2018 with a bid of $185,000 for a heterozygous polled Purebred bull, and $280,000 was been paid this year for a Fullblood heifer by an American syndicate.
This 17 month old heifer is an October 2017 Fullblood calf and was offered from Scott de Bruin’s Mayura Wagyu from Millicent, South Australia. Surpassing the previous all-breeds beef cattle record of $190,000 held by an Angus heifer, she was knocked down for a record $280,000 to Brian Stamps from Oklahoma in the USA. Second highest Wagyu heifer price also exceeded the Angus record and went to Trent Bridge K0034, a September 2014-born cow, sold in calf, from Armidale, NSW and bought for $200,000 by GeneFlow, a recently-launched IVF company based out of Tocumwal in southern NSW. The Trent Bridge cow has the highest marbling score (+2.4) of all registered Wagyu females recorded on BREEDPLAN and is from parents bred by the Perry family.

The Elite Wagyu Genetics Sale turned over $1.74 million in 2019 from 101 Lots. Despite the record prices, some excellent genetics didn’t get a bid as buyers were spoilt with options. Demand for Polled genetics appeared to wane but many Fullblood purchases were driven by the need to increase marbling in polled Wagyu herds. Correlations between EBVs and bid prices confirmed a strong association between Marble score EBV and bid price for Fullblood heifers (R = +0.51 in both females and semen, and +0.49 for bulls\(^{AWA, 2019}\)). Marble fineness EBV correlation was highest in bulls (R = +0.51). Correlations were mainly positive with EMA EBVs, but Carcass weight EBV was largely overlooked (ranging from -0.31 to +0.17, with an overall R = -0.17 across all Fullbloods). Rump backfat thickness EBV was strongly negative for semen (R = -0.51) with a flat tendency overall of +0.03 across all Fullbloods.

AWA recently improved the Fullblood Terminal $Indexes and introduced another two. The association between $Indexes and Bid prices for Fullbloods in the recent 2019 auction are generally weakly positive overall with the strongest found for F1 Terminal $Index. Wagyu International uses different weightings for traits that are considered to be of economic significance and these are expressed as a Carcass Indicator (wi CI) and a Maternal Indicator (wiMI). wiCI has incorporated Marble fineness since it was first reported in BREEDPLAN and Subcutaneous fat thickness is negative - as it is in Yield Score in Japan. The association between wiCI and Bid price from the 2019 Elite auction is illustrated above and buying drivers were more closely aligned with the traits used in wiCI than in the $Indexes. The
implications are that the weightings used by Wagyu International for the Carcass Indicator are closely aligned with those that were used by the highest Bidders for each Lot. The F1TI gave the second closest association in this data.

Three out of eleven batches of Polled Purebred genetics were successfully sold, with 30 straws of semen selling for an average of $533; but all females, bulls and embryos were passed in. Despite the low numbers involved, strong associations were found with Bid prices for Polled Purebred bulls. However, bidders were not prepared to reach vendors’ expectations. Regression between bid prices was highest with wi MI (maternal traits) but the correlation was strongly negative (R = -0.90). This confirms that there is no interest in growth or milk in the evolving Polled Wagyu herd and is exactly as expected as it is terminal. The second highest regression was with wi CI (R = + 0.83) and this was positive. Third was F1 Terminal Index, and finally Fullblood Terminal Index and Self Replacing Index had lowest bearing.

There was no premium offered for homozygous polled (PP) genetics over heterozygous polled (PH) genetics. Strongest associations of bid prices were with the following carcass traits: Marble score (R = +0.74), Marble fineness (R = +0.60 and EMA (R = +0.96). Maternal traits were strongly negatively associated: 400 day weight (R = -0.84) and Carcass weight (R = - 0.64). A few of these traits are shown in the chart.

The breeding merit of some lots was higher in 2019 than the previous year, but, despite this, bids did not reach reserve price. The bidding in 2019 stopped at $30,000 for Poll Wagyu Nightfall. His full brother, Poll Wagyu Midnight M0775, sold for $185,000 in 2018. They are both carriers for F11 and heterozygous polled. They both have genomic EBVs and this is where the major difference is. The accuracies are almost the same but Nightfall has the tiniest advantage for five traits. EBVs for almost all traits are higher for Nightfall and to put them in perspective, Nightfall has a F1 terminal Index of +$162 while Midnight is lower by 26%.

Either sufficient semen has been sold from Midnight since his purchase a year ago to satisfy demand for this genotype, or else breeders of polled genetic give no credence to genomic EBVs for no one to have offered market value for Nightfall with superior gEBVs at this sale. In 2017, 12 out of 20 polled Purebred Wagyu bulls sold for an average of $9,077 with a top price of $15,000. The following year, Poll Wagyu Midnight with improved carcass EBVs sold well and exceeded expectations with the record price of $185,000. A year later, his brother with better breeding value was passed in on $30,000. The EBVs, $Indexes and wi Indicators are charted below.

Midnight semen sold for $1,700 a straw last year, and $533 in 2019.
It is speculated that market price for high carcass quality Polled bulls will be from $30,000 to $50,000.

**BLUP analysis in Japan.**

A step back in time to review progress from genetic gain in Japan is the second component in this report. Prior to 1968, visual assessment to select Wagyu for breeding was based on the principle that soft and elastic hide, fine and soft hair, fine textured horn, and clean-cut face would produce high quality beef. In 1968 this changed when a testing system was adopted using a test station within each prefecture for both performance and progeny testing of the young bulls. There were three steps that were involved: Initially, candidate bulls produced from planned mating using superior sires and dams that had been selected on visual judging were gathered and performance tested for 112 days at a prefectural test station after weaning. Based on their growth rates, the best young bulls were selected for test mating. Progeny (6 to 10 animals) were performance tested over 364 days. From these, the best bulls were selected based on the carcass records from their progeny. This process continued but, in the late 1980s, three prefectures (Ōita, Hyōgo, and Kumamoto) began on-farm progeny testing based on best linear unbiased prediction (BLUP) within each prefecture by entering carcass records from carcass markets and pedigree records from registry associations. Under this program, all sires and dams of the steers and heifers shipped to the carcass markets were simultaneously evaluated. The predicted breeding values from the BLUP analysis were used for planned mating between superior sires and dams. This resulted in the production of candidate bulls. Furthermore, on-farm culling for breeding dams, which were based on breeding values, was introduced. Until then, selection had been entirely focused on the sire. On-farm progeny testing became popular and was rolled out in additional prefectures. Initially, the primary selection for the Japanese Black bulls was on carcass quality traits while selection for the Japanese Brown breed was based on growth traits. After favouring growth for several years, carcass quality was selected for in Japanese Brown but their large size has prevailed through to the Japanese Brown of the present. The rate of genetic improvement in Wagyu in Japan under the three historic methods – visual assessment until 1968; then progeny testing at prefectural stations through to mid-1980s; and finally on-farm progeny recording for BLUP analysis that were recorded through to 2003 – is reported. The three regions where breeding merit was measured are Kumamoto on Kyūshū Island (Japanese Brown/Red Wagyu/Akaushi), Hyōgo on the mainland with Tajima strain of Japanese Black, and Ōita which is next to Kumamoto on Kyūshū Island acquired several sons from Dai 7 Itozakura for the Japanese Black herd.

**Average carcass performance from the two breeds from three prefectures in Japan:**

<table>
<thead>
<tr>
<th>Prefecture</th>
<th>Kumamoto</th>
<th>Ōita</th>
<th>Hyōgo</th>
<th>Kumamoto</th>
<th>Ōita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Steers</td>
<td></td>
<td>Heifers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcass weight (kg)</td>
<td>441.5</td>
<td>431.9</td>
<td>382.1</td>
<td>404.9</td>
<td>382.2</td>
</tr>
<tr>
<td>Loin area (cm²)</td>
<td>49.2</td>
<td>49.6</td>
<td>49.0</td>
<td>47.4</td>
<td>48.3</td>
</tr>
<tr>
<td>Rib fat thickness (mm)</td>
<td>70.7</td>
<td>70.9</td>
<td>67.6</td>
<td>69.7</td>
<td>68.5</td>
</tr>
<tr>
<td>S.c. fat thickness (mm)</td>
<td>24.7</td>
<td>27.2</td>
<td>20.8</td>
<td>27.8</td>
<td>30.6</td>
</tr>
<tr>
<td>BMS grade</td>
<td>3.4</td>
<td>5.7</td>
<td>6.4</td>
<td>3.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Fattening period (days)</td>
<td>446.4</td>
<td>603.6</td>
<td>693.4</td>
<td>463.2</td>
<td>596.0</td>
</tr>
<tr>
<td>Slaughter age (days)</td>
<td>737.8</td>
<td>879.7</td>
<td>965.9</td>
<td>769.1</td>
<td>890.3</td>
</tr>
</tbody>
</table>

Japanese Black in Hyōgo had greater marbling (BMS) than Japanese Brown, but with a longer feeding period which resulted in finishing at an older age (P < 0.001). The Japanese Black steers in Hyōgo had thinner subcutaneous fat thickness and smaller carcass weight than Japanese Black from Ōita, but the growth performance in Ōita was superior to that in Hyōgo. Japanese Brown had higher carcass weight than Japanese Black from a shorter feeding period.
Moderate to high heritabilities ($h^2$) were obtained for all carcass traits for the three prefectures: Carcass weight 0.44 to 0.50, rib fat thickness 0.40 to 0.47, loin muscle area 0.44 to 0.54, subcutaneous fat thickness 0.50 to 0.57 and marbling (BMS) 0.56 to 0.64. Generally, heritability was lower for traits for Japanese Brown in Kumamoto and for Japanese Black in Ōita, and was highest for Japanese Black in Hyōgo.

Pedigrees for the 126,937 animals in the study were traced back to ancestors that were born in the 1950s. Wagyu cattle in Japan had been used as draught animals for centuries but became increasingly important as beef animals during 1960s. By 1968, performance and progeny testing were introduced to the beef industry in Japan. Genetic trends were estimated by averaging predicted breeding values of dams that were reproducing and that had calves that were born during the same year in each prefecture. Genetic gain per year during the period of visual judging was small. Genetic gains in the period during the progeny testing in prefectural test stations increased for most traits. After adopting on-farm progeny testing with BLUP analysis, genetic changes for all carcass traits became significant.

The results clearly show the ineffectiveness of visual assessment applied in the first phase for three carcass traits in the charts above. The response to “Visual selection” is shown in the bars to the left of each chart. Improvement from progeny testing in test stations in the middle phase for a few traits is shown in the middle cluster of bars above “Progeny – on station”. Among them, BMS in both Japanese Black populations and carcass weight in the Japanese Brown were most notable. Interestingly, positive trends in these cases began simultaneously around 1978, which was about 10 years after beginning performance and progeny testing in test stations. Beef marbling in Japanese Brown only became an important objective in the late 1970s so larger improvements in genetic gain for BMS in Japanese Brown only began to be demonstrated during the 1980s. In Hyōgo prefecture, a strong negative trend was evident in subcutaneous fat thickness during the progeny testing. After an increase in subcutaneous fat thickness in Japanese Brown in Kumamoto during the first two phases, it was strongly reduced during the final BLUP analysis phase. These outcomes had not been specifically selected for so were incidental but nevertheless statistically significant. In addition, a negative trend is apparent for carcass weight. Hyōgo prefecture is famous for the production of highly marbled beef with thin subcutaneous fat – the notorious ‘Kobe beef’. It is important to note
that a maximum carcass weight was imposed for certification as Kobe brand beef at the carcass market in Kobe city and the lighter Tajima carcasses still prevail to the modern day globally. The on-farm progeny testing program that is based on BLUP began in 1983 in Oita, and in 1987 in Kumamoto and Hyōgo. The genetic gains achieved in the final phase in these charts (right hand cluster above ‘Progeny – on farm BLUP’) suggested that on-farm progeny testing would effectively enhance the genetic improvement of all carcass traits of Wagyu populations when it is applied and so it rolled out to the other prefectures through Japan. Because progeny testing in test stations was continued after on-farm progeny testing began, genetic improvement in the final stage may reflect the summation of genetic improvements achieved by both programs. The overall results indicate that an on farm progeny testing program, combined with BLUP, is very powerful for genetic improvement of carcass traits in beef cattle. After the on-farm program began, predicted breeding values for the reproducing dams became available to farmers. The benefits from the effective selection of reproducing dams based on their predicted breeding values have enhanced genetic gains during the period when on-farm progeny testing and genetic evaluation were combined.

Progeny tests in Japan

During this period, the first sires that were progeny tested had the results of six (Dai 7 Itozakura) to eight (Yasufuku) progeny displayed on the registration certificates of their registered offspring. The average of +4.1 for BMS (旧 or “old system”) from Yasufuku’s eight progeny during his “indirect” test, 0.83 kg/day for daily gain, 16 mm for subcutaneous fat thickness and 49 cm² for rib eye area is shown to the left in an extract from his leading son Yasufuku 165-9’s registration certificate. Yasufuku’s registration gave a Yield estimate of 83.4, with DG, REA and BMS. Even though this is not shown on the certificates, Yasufuku’s dressed weights were an average of 354.1 kg from an average slaughter weight of 541.8 kg at an average age of 20.5 months of age. Semen from all sires was distributed enabling more progeny from each sire to be evaluated progressively after the initial ‘proof’. Predicted breeding values (PBVs) were calculated using BLUP analysis and reported for the top hundred or so sires in each prefecture periodically. They were sorted by BMS score and the accuracies were reported with each PBV. In addition to Carcass weight, Marbling and Rib eye area PBVs, Rib thickness PBV was reported. Rib thickness is one of several measurements that are used during grading to obtain Yield Score JMGA 2000:

\[
\text{Yield Score estimate} (\%) = 67.37 + 0.300 \times \text{Rib eye area (cm}^2) + 0.667 \times \text{Rib thickness (cm)} - 0.025 \times \text{Cold left side weight (kg)} - 0.896 \times \text{Subcutaneous fat thickness (cm)}.
\]

An additional 2.049 is added for Wagyu carcasses. Yield score is reduced by one score if the intermuscular fat thickness is relatively thick or if the round is too thin and if the proportion of fore- and hind-quarters is considered undesirable. Rib thickness is the width of intercostal muscles and excludes subcutaneous fat thickness on the exterior. Subcutaneous fat is considered to be antagonistic to yield so it is multiplied by a negative factor in the Yield Score calculation in Japan. One 1989 sire had 20 progeny in his test but most tests from the early 1990s were carried out on an
average of 10 per sire. After another ten years, and subsequently, the number of progeny used as ‘proof’ in the indirect test increased to around 20. The more popular sires have data from hundreds of their progeny over time that are incorporated through BLUP analysis into the breeding values published by each prefecture. The results are compared within each prefecture. The distribution of raw data for each sire has been analysed and compared with breeding values. No association was detected between BMS progeny test result from 1970 and 1980 sires against their subsequent breeding value. Grading of all carcasses is under the authority of JMGA and the process is continually under review. The minimum IMF% for each BMS in 1988 is a large blue dot in the chart above. By 2008 it had increased and the minimum IMF% per BMS is a black dot. Subsequently, digital imaging from the Obihiro University camera of carcasses that had been JMGA graded shows each result as a X Grose 2011. They have merged into bars where they are the most abundant. A large variation in IMF% values for each BMS is displayed and they are mostly above the designated minimum standard for each BMS. However such variability from BMS grading would be expected to influence statistical analysis of phenotypic data. Nevertheless, progeny test results that had been graded under the former BMS are classified as the old system and recorded as +4. 4(旧). Results from the modern system do not have a sign and look like this example: 3.0(新). No association was found between progeny test results from between six and 13 progeny per test against sire breeding value. An analysis was carried out with raw data from the modern BMS grading system. There was a positive trend between BMS (新) progeny tests and breeding values from tests with approximately 20 progeny (R = +0.39, blue circles in the chart below). It was weaker but nevertheless positive from tests with between 6 and 13 progeny per sire (R = +0.17, yellow squares).

The standard deviation of raw data was high and it is caused by environmental influences, including maternal contribution, during progeny tests. The narrowest spread was from a sire (black bars in the chart to the right, above) with an average BMS of 10.24 from 21 progeny. The BMS grades were between 8 and 12, and the standard deviation was 1.18. Most divergence was from a sire with an average in his 21 progeny of 8.76, from a score of 4 to 12 in nine different grades, and a standard deviation of 2.57 (shown with red bars in the chart). The extent of the variation in progeny results in these two unrelated sires in Japan, illustrates how deceptive it could be to try and predict an animal’s performance from just one offspring, or five, or even ten? Accordingly, it is concluded that averages alone from 10 progeny per sire do not provide an accurate estimate of breeding merit, but that it is possible that a trend could be obtained from 20 or more progeny. However, only a BLUP analysis will provide breeding values.
Breeding values have been incorporated onto registration certificates in Japan for several years on a percentile basis below the progeny test results. The breeding value of each animal is compared with the estimated breeding values within the recording prefecture. This rating permits animals from different prefectures to be compared and is displayed for females too. The Top 25% are designated to be “A”, those from 25-50% are “B”, while “C” are considered to be average or below. The group is displayed after the 育種価 in a string of six capital letters, in the following order:
- Carcass weight breeding value
- Rib eye area breeding value
- Rib thickness breeding value
- Subcutaneous fat thickness breeding value
- Yield estimate breeding value
- Marbling (BMS) breeding value.

An example from a Registration certificate is the son of Yasufuku 930 and Harumi. Maternal grand-sire is Kikuteru Doi and maternal grand-dam is Tetsuya (who was sired by Yasutani Doi). The breeding value score on the certificate is ‘BABCBA’. A is for Rib eye area and BMS PBVs, B is for Carcass weight, Rib thickness and Yield estimate PBVs, and C is for Subcutaneous fat thickness PBV. These PBVs align with the expectations from his pedigree. His performance test DG was 1.31 kg/day and progeny test results were DG 0.92, BMS 2.6, REA 47, and Yield 73.2%.

Finally, Japan has progressed to single step genomic BLUP. The conversion to predicting breeding value from genomic BLUP compared to pedigree BLUP has improved accuracy to the largest extent to those traits that have had lower accuracy. Accordingly, REA accuracy has improved by a third, BMS has almost doubled while subcutaneous fat thickness accuracy has raised the most by 130% to just over 0.5.

BLUP analyses outside Japan

The use of digital imagining as pioneered at Obihiro University has enabled carcass measurements to be recorded in countries where local carcass grading is inadequate for Wagyu carcasses. Increased accuracy from measuring phenotypes increases heritabilities of some traits. In addition to that, Australia rolled out single step genomic BLUP in 2017 where EBVs for Wagyu are reported by the Australian Wagyu Association in BREEDPLAN. A few operations conduct their own EBV evaluations analysing data from either digital imaging or local AUS-MEAT carcass grading in independent BLUP analyses.

In USA, expected progeny differences (EPD) are reported by the American Wagyu Association for four traits. 113 Wagyu sires have marbling EPDs that have been generated from 4,066 half-bred Wagyu progeny that were raised in contemporary groups. It appears that a minimum of 80 progeny from the non-Wagyu dams are required to generate EPDs that have sufficiently high accuracies for a parent. EPDs have not been published for females.

Marbling and tenderness

The supreme eating quality from the Wagyu breed is attributed mainly to ‘marbling’ which is intramuscular fat (the fat within muscle, ‘IMF’). In Japan, marbling with a fine appearance – like frost ‘Shimo-furi’- is highly valued, while coarse marbling is inferior. Marbling contributes to the tenderness of beef because IMF deposits located between muscle fibre bundles disrupt the connective tissue of perimysium. There is an average of almost 1000 flecks of fat in the cross section of the eye muscle with fine marbling so more connective tissue is disrupted.

Foundation Wagyu sires with highest estimated breeding values (EBV) for fineness of marbling are: Michifuku (+0.47), Kitaguni Jr (+0.34), Itozuru Doi TF151 (+0.30), Itoshigenami TF148 (+0.27) and
Yasufuku Jr (+0.25). The highest negatives are Itoshigefuji TF147 (-0.44), Kikuyasu 400 (-0.39) and Yukiharunami 4 (-0.37) AWA, 2019.

Marbling and lipid content

IMF content is generally related to the tenderness and juiciness of meat. The ‘eating quality’ of meat is largely determined by the sensory characteristics such as taste, tenderness, juiciness and aroma. In addition to IMF content, other factors have been reported as affecting the eating quality of meat, including fatty acid composition. In addition, beef palatability has been shown to be related to water-soluble compounds, such as free amino acids (e.g. glutamic acid and aspartic acid), peptides (e.g. carnosine) and nucleotides (e.g. inosine 5’-monophosphate ‘IMP’), as well as sugars (e.g. glucose and fructose). Sugars could contribute to the sweetness and flavour of meat upon cooking, due to the Maillard reaction. In recent years, consumer demand for healthier meat has grown but there may be compromises with the eating quality of meat.

Improvements in the chemical traits of meat can be achieved through manipulation of both genetic and environmental factors – such as from aging, the diet and feeding system. Genetic effects in some traits have been reported; for example, fatty acid composition is a heritable trait, with heritability ranging between 0.31 and 0.73 in the Trapezius muscle, and between 0.58 and 0.78 in the Longissimus muscle of Japanese Black cattle. Most heritability estimates for water-soluble compounds were lower than 0.30 but these traits were affected by aging over a few weeks so they can be more successfully enhanced by aging than by selection.

In addition to its high level of marbling, Wagyu beef has a higher percentage of mono unsaturated fatty acids (MUFAs) than other breeds. A higher percentage of MUFAs leads to a lower melting point for the fat, which contributes to the softness of bovine fat and improved beef flavour. It has been shown to decrease the circulating concentration of low-density lipoprotein cholesterol. Therefore, the fatty acid composition has recently become an important consideration in the beef industry, especially in Japanese Black cattle.

The fatty acid composition in cattle is less dependent on diet than in mono-gastric animals. However, diet does still influence the bovine fatty acid composition. Different Japanese Black sire lines have significantly different fatty acid composition so this suggests that fatty acid composition is controlled by genetic factors. Many genes have been found to be associated with fatty acid composition have been identified in Japanese Black cattle.

Stearoyl-CoA desaturase and lipids

Stearoyl-CoA desaturase (SCD) was one of the early genes to be associated with fatty acid composition in beef Taniguchi, 2004. The SCD gene originally was made of the amino acid called valine (V type) but it was then substituted through a mutation to alanine (A type). The properties of these genes were compared from different SCD genotypes in Japan.
SCD genotype | Mono-unsaturated fatty acids (%) | Melting point (°C) |
--- | --- | --- |
AA | 58.8 ± 0.1<sup>a</sup> | 25.4 ± 0.2<sup>a</sup> |
VA | 58.2 ± 0.1<sup>b</sup> | 26.1 ± 0.1<sup>d</sup> |
VV | 57.1 ± 0.3<sup>c</sup> | 27.6 ± 0.3<sup>f</sup> |

There was a positive association between MUFA content with genotype. The genotype AA showed 1.7% higher MUFA percentage than the genotype VV. However, there was a large variation in MUFA content within each genotype with considerable overlapping. There was a negative correlation between melting point of intramuscular fat on genotype. There was also large variation of melting point of intramuscular fat of the raw data within each genotype.

The variation within each genotype from the trial data is illustrated below. An outlier with VV genotype had a MUFA of 72.8% which is higher than all of those that had the AA genotype. To the other extreme, an animal with the AA genotype recorded MUFA of 50.5% which is lower than all of those with VV genotypes.

The authors concluded that the SCD genotype is not the only cause of genetic variation in fatty acid composition of Japanese Black carcasses. Other genetic factors were also considered likely to contribute to the variation of MUFA percentage in intramuscular fat.

Another trail found that the average effects of gene substitution of the SCD type A gene on the monounsaturated fatty acid (MUFA) percentage and the melting point of intramuscular fat were approximately +1.0% and -1.0°C, respectively. However, no effect of SCD or SREBP-1 genotypes on any representative carcass traits of Japanese Black in the field population was observed (Mannen, H. 2011).

The abundance of tests that have been reported in USA reveals the frequency of genotypes in the more popular families in the global Black Wagyu population. Foundation sires that have been tested AA in the SCD test are Fukutsuru, Kikuyasu 400, Kitateruyasu Doi, Michifuku, Sanjirou and Yasufuku Jr. Both Fukutsuru 068 and Kitateruyasu Doi are descendants of sires that convey high oleic acid through tested progeny that were recorded in Hyōgo prefecture in Japan so they warrant further mention in that section later in this report. Michifuku, Sanjirou and Yasufuku Jr - contribute other major carcass attributes to their offspring so the potential added benefit of some additional lipid is a potential bonus when they are used.

The exception is Kikuyasu 400. He is line-bred within the Kikumi-Doi family and reportedly weighed 900kg which is heavy for a Tajima bull. He is within the Top 18% for Eye muscle area EBV so is well muscled. Kenichi Ono wrote that Kikuyasu 400’s sire, Kikuyasu Doi has the lowest growth rates amongst the Kikumi-Doi family. Kikuyasu 400 progeny in Australia recorded the lightest induction weights after backgrounding and they required 24 months on feed. Kikuyasu 400 could have a role in boutique feeding situations where a premium can be obtained to compensate for the excessive feeding period required in order to obtain favourable eating quality at three years of age. Even though Kikuyasu Doi was considered to be amongst the most influential 12 sires in Japan in the 1970s, his legacy does not appear to have prevailed beyond that. Some females from combinations of Kikumi-Doi lines with Tafuku-Doi/Yasutani-Doi genetics – such as Kikutsuru who was mother to both Tanifuku Doi then Dai 2 Yasutsuru plus many daughters – have made lasting contributions (Ono, K., 1999, 2002, 2007, 2012, 2017).
Several genes have an association with lipid content

Several genes affecting fatty acid composition have been identified. Sterol regulatory element binding protein-1 (SREBP-1) regulates gene transcription (copying) activation by binding sequences that are contained in the promoters of downstream genes, including the SCD gene, to the sterol regulatory element. The intron polymorphism of SREBP-1 also affects the fatty acid composition in bovine adipose tissue. Bovine fatty acid synthase (FASN) generates a multifunctional enzyme that regulates biosynthesis of long-chain fatty acids in mammals. FASN genotypes affected the fatty acid composition of dorsal, intramuscular and intermuscular fat in an F2 population from Japanese Black and Limousin cattle. Representative genes such as SCD and FASN have been used as DNA markers to select sires. Although the mechanism in adipose (fat) tissue is extremely complicated, several additional genes have been identified and confirmed as being either associated with or are responsible for the fatty acid composition in Japanese Black cattle.

The following genes were reported to affect fatty acid composition: adipocytes fatty acid binding protein (FABP4), liver X receptor α (LXRα), elongation of very-long-chain fatty acid 5 (ELOVL5), fatty acid desaturase 2 (FADS2), acetyl-CoA carboxylase-α (ACACA), and urotensin 2 receptor. The single and epistatic (joint) effects of four genes (FASN, SCD, SREBP1, and GH) with a total of five variations were evaluated on the fatty acid composition of the longissimus thoracis muscle and carcass and meat quality traits in 480 Japanese Black cattle. The genotypic and allelic frequencies for the five polymorphic genetic markers in the four genes are shown in the table below. The major alleles of each marker were as follows: allele TW in FASN, allele A in SCD, allele V in GH<sup>1127V</sup>, and allele T in GH<sup>T172M</sup>. The allele frequencies for FASN were substantially biased toward the allele TW and there were only four animals with the genotype AR/AR. There was little bias in the allele frequencies for SREBP1.

<table>
<thead>
<tr>
<th>Marker</th>
<th>Genotype and genotypic frequency</th>
<th>Allelic frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>FASN</td>
<td>TW/TW 0.71 TW/AR 0.28 AR/AR 0.01</td>
<td>TW 0.85 AR 0.15</td>
</tr>
<tr>
<td>SCD</td>
<td>AA 0.50 VA 0.42 VV 0.08</td>
<td>A 0.71 V 0.29</td>
</tr>
<tr>
<td>SREBP1</td>
<td>SS 0.27 LS 0.40 LL 0.24</td>
<td>S 0.51 L 0.49</td>
</tr>
<tr>
<td>GH&lt;sup&gt;1127V&lt;/sup&gt;</td>
<td>VV 0.56 LV 0.35 LL 0.09</td>
<td>V 0.74 L 0.26</td>
</tr>
<tr>
<td>GH&lt;sup&gt;T172M&lt;/sup&gt;</td>
<td>TT 0.71 MT 0.027 MM 0.02</td>
<td>T 0.85 M 0.16</td>
</tr>
</tbody>
</table>

Significant single effects of FASN, SCD, and GH<sup>1127V</sup> polymorphisms on the fatty acid composition were detected. Combined response to the single effects on each fatty acid ranged between 5 and 30% of the total. When the genotypes of all three markers (FASN, SCD, and GH<sup>1127V</sup>) were substituted from the lesser effect allele to the greater effect allele, the proportion of C18:1 (oleic acid) increased by 4.46%. Polymorphisms in 2 fatty acid synthesis genes (FASN and SCD) independently influenced fatty acid composition in the longissimus thoracis muscle.
In a previous study, significant effects of the FASN genotype were reported on the lipids C14:0, C14:1, C16:0, C16:1 and C18:1 content of the trapezius muscle intramuscular fat in Japanese Black populations. In the present study, the same effect of the FASN marker was detected for the intramuscular fat of the longissimus thoracis muscle.

In another study, the group with genotype LL for the GH marker had a greater percentage of C14:1 and C16:1 and a reduced percentage of C18:0 in longissimus thoracis muscle lipid, compared with the group with genotype VV. In this study, similar effects were detected at the same mutation site.

**Single nucleotide polymorphism and carcass traits**

Moving away from fatty acids, endothelial differentiation sphingolipid G-protein-coupled receptor 1 (EDG1) gene was associated with the BMS level in a Japanese Black beef cattle population in Oita prefecture. The G allele is associated with a high level of BMS. This association was investigated in other prefectures.

The effect of the genotype on the BMS level was not statistically significant in the Kagoshima prefecture population (P > 0.05) in which the predominant breeding objective has been for carcase weight. BMS has been historically selected for in the Miyazaki and Nagasaki prefectures so many quantitative trait loci for the BMS are thought to have been fixed in those populations. The carcase weight, rib loin area and rib fat thickness values were significantly higher in the GG homozygotes than in the AA homozygotes, and the values in the heterozygotes were intermediate between those in the 2 homozygotes. Thus, just like its effect on the BMS, the effects of the G allele on carcass traits other than the BMS, if any, seemed to be favourable rather than deleterious.

**Growth hormone and performance**

Another gene that has been found to have important roles in regulating animal growth and production is the growth hormone (GH) gene that has been extensively investigated in Japanese Black cattle. The frequency of the B allele was higher (0.421) than that of A (0.269) and C (0.311). High carcase weight (p < 0.05) and low beef marbling (p < 0.01) were associated with allele A, whereas beef marbling was increased by allele C (P < 0.05).

The following year, other workers found that allele A gave greater rib thickness and lower melting point of fat while allele B gave higher oleic acid fatty acid % (C18:1) (P < 0.05). Allele C gave higher oleic acid C18:1, monounsaturated fatty acid (MUFA), unsaturated fatty acid (USFA) percentages (P < 0.05). It also gave lower saturated fatty acid (SFA) percentages, higher MUFA/SFA and USFA/SFA ratios, and lower melting point (P < 0.05).

The distribution of GH genes is the result of selection pressure that has applied over the past and is directly related to prefecture and Wagyu strain. The Tajima strain, descendants originating from Naka-doi and subsequently through Tajiri, predominantly have B and C. Strains from Okayama and Shimane prefectures predominantly have A and C alleles. The other strain that is present amongst the exports from Japan is the Kedaka line from Tottori which is predominantly A. The foundation animals which form the basis of the Wagyu population outside Japan combine pairs of A, B and C alleles and are largely influenced by original family line or prefecture of origin.

Distribution of growth hormone genes from prefectures:

<table>
<thead>
<tr>
<th>Prefecture</th>
<th>Name of strain</th>
<th>Distribution of GH gene in each strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Hyōgo</td>
<td>Nakadoi-kei</td>
<td>2</td>
</tr>
<tr>
<td>Okayama</td>
<td>Fujiyoshi-kei</td>
<td>32</td>
</tr>
<tr>
<td>Shimane</td>
<td>Itozakura-kei</td>
<td>46</td>
</tr>
<tr>
<td>Tottori</td>
<td>Kedaka-kei</td>
<td>74</td>
</tr>
<tr>
<td>Hiroshima</td>
<td>38 lwata-kei</td>
<td>81</td>
</tr>
</tbody>
</table>
Summary of the effects that each GH allele has on major carcase traits in Japanese Black:

<table>
<thead>
<tr>
<th>Carcase trait</th>
<th>GH allele</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcase weight</td>
<td></td>
<td>Large</td>
<td>Medium</td>
<td>Small</td>
</tr>
<tr>
<td>Marbling (IMF%)</td>
<td></td>
<td>Lightest</td>
<td>Medium</td>
<td>Highest</td>
</tr>
<tr>
<td>Rib loin area</td>
<td></td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
</tbody>
</table>

The effects of A and C allele are antagonistic between Carcase weight with both marbling (IMF%) and rib loin area while the B allele is intermediate. The implications from selection solely by GH allele will have a significant influence on the genotype of a herd or population.

Mr Shogo Takeda advocated the Fullblood Rotation Program when he became concerned that too much selection pressure was being applied towards marbling at the expense of frame size when Wagyu were introduced from Japan to the Americas and Australia. The principle is to cross cows from Frame sires to Marbling sires. Cows from Marbling sires are joined to Frame sires. Classification is based on prefectural content (also called 16/16). More information is given at http://www.wagyuinternational.com/rotation.php. A deviation from this principle – such as selecting entirely on GH results from Exon 5 tests – will have the same consequence that resulted from selecting too heavily on Tajima content. The C allele would be more frequent in B and D sires in the Wagyu Fullblood Rotation as it is influenced by Tajima content. The A allele would be located in the A group for Okayama and Itozakura strains while A allele from Kedaka strain would constitute C group. In my opinion, the Fullblood Rotation Program - in conjunction with genomic EBVs as each generation extends the distance from origin - is important for sustainability of the Wagyu breed.

Oleic acid composition

In general, traits in cattle - such as fatty acid composition - have been considered to be polygenic (many different genes). Although the mechanism for adipose tissue development is extremely complicated, several genes have been identified and confirmed as being either associated with or responsible for the fatty acid composition in Japanese Black cattle. Oleic acid is the MUFA that is favourably associated with flavour. Oleic acid and MUFA are generally regarded to have a favourable health profile for human heart disease. The seven Japanese Black sires that have produced progeny with the highest oleic acid content in Hyōgo, and their relations with Foundation sires that were exported from Japan are tabled below.

<table>
<thead>
<tr>
<th>Bull in Japan</th>
<th>Name of exported foundation sons</th>
<th>Oleic acid</th>
<th>Foundation 1st generation</th>
<th>Progeny registered</th>
<th>SCD test</th>
</tr>
</thead>
<tbody>
<tr>
<td>第2鶴雪土井 ****</td>
<td></td>
<td>58.5%</td>
<td>No progeny exported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>照長土井 *</td>
<td>Kitateruyasu Doi “003”</td>
<td>58.4%</td>
<td>Kitateruyasu Doi “003”</td>
<td>3,884 AUS / 194 USA</td>
<td>AA</td>
</tr>
<tr>
<td>第2照久土井</td>
<td></td>
<td>57.9%</td>
<td>No progeny exported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>第2安鶴土井 **</td>
<td>Fukutsuru J068</td>
<td>57.9%</td>
<td>Kitatsurikiku Doi “007”</td>
<td>958 AUS / 370 USA</td>
<td>AA</td>
</tr>
<tr>
<td>第2安鶴土井 **</td>
<td>Kitatsurikiku Doi “007”</td>
<td>57.9%</td>
<td>Kitatsurikiku Doi “007”</td>
<td>958 AUS / 370 USA</td>
<td>AA</td>
</tr>
<tr>
<td>谷福土井 ***</td>
<td>Kikutsuru Doi TF146</td>
<td>57.8%</td>
<td>No progeny exported</td>
<td>40 AUS / 37 USA</td>
<td>AA</td>
</tr>
<tr>
<td>谷美土井</td>
<td></td>
<td>57.0%</td>
<td>No progeny exported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>鶴丸土井 *****</td>
<td></td>
<td>56.8%</td>
<td>No progeny exported</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The second highest Hyogo sire, Terunaga Doi, is father of Kitateruyasu Doi, the Westholme foundation bull also known as “003”. He is popular for producing Fullblood 450-500 day grain finishing from the performance of his progeny and high IMF% estimated breeding values. With 3,884 registered progeny in Australia he is amongst the more popular foundation sires and this is primarily from observations of his
progeny from commercial lotfeeding in Australia. Subsequently his carcase traits were substantiated when single step genomic EBVs were published. Kitateruyasu Doi is amongst the leading sires outside Japan for overall eating quality from Fullblood grain finishing as a result of his high oleic acid content.

** The fourth highest oleic acid content Hyogo bull is Dai 2 Yasutsuru Doi. He preceeded Yasufuku and was extremely popular from the quality of his meat in Japan but growth of his progeny was slow. Two of his sons were foundation exports from Japan. Progeny from Fukutsuru 068 are light in weight but high in back fat and waste so these traits diminished his following in Australia during early evaluations from feedlots before genomic EBVs were available. Marble score (IMF%) EBV is below average. His contribution in Fullblood breeding is from high milking EBVs because milk production is low in high marbling Black Wagyu. The number of registrations in Australia ranks him eleventh. However in USA where credence is given to the SCD gene test results he is more popular and ranks in eighth place by number of registrations amongst the Foundations. Despite very favourable flavour, production performance is light.

*** Tanifuku Doi, fifth on the list, is sire of Foundation bull Kikutsuru Doi TF146 who shares Yasutani Doi:Kikumi Doi lines almost equally. Despite strong IMF% EBV his registration count is low in Australia and AA for SCD has not made any impression in USA.

**** Son of Dai 2 Yasutsuru Doi (who himself is placed fourth for oleic acid content). Another of his sons was promoted for crossing over Holstein cows to improve eating quality and 100,000 straws of his semen was sold.

The common link between Tanifuku Doi and Dai 2 Yasutsuru Doi (both high oleic acid Hyogo sires) is their mother Kikutsuru - who happens to be my favourite Japanese Black dam.

In my analysis of pedigrees that I have been able to trace from four of the sires above, the common links going back to up to nine generations at least five times are Kikumi Doi and Tafuku Doi. Kitateruyasudoi is the leading Foundation sire that is directly related to one of the highest oleic acid sires in Hyōgo and that also has with a full complement of important carcass EBVs for quality.

Whole genome sequencing

A test kit for oleic acid content for Wagyu is highly desirable but whole genome sequencing may provide the solution in predicting oleic acid in conjunction with other major fatty acid content. Many genes are known to be involved so a blanket approach is required. This outcome is preferable to several single tests being carried out in tandem with the whole genome test. It is possible too that feed efficiency may be subject to genomic control so this is another complex trait that is being evaluated.

Accurate phenotypic (physical or chemical) measurements are taken and compared with the thousands of SNPs in the genomic-wide association study (GWAS). In this way, associations are made between SNPs and complex traits. Heritabilities are increasing from trials with 770k SNPs compared to those from low density SNP arrays.

This work is underway with fatty acid content in cattle. The composition of seven fatty acids was assessed in Japanese Black cattle. The estimates using the GBLUP and BayesBian methods were superior to those obtained by the PBLUP method. The Bayesian method performed similarly to GBLUP for most of the studied traits but substantially better for those traits that were controlled by SNPs with complex effects.
These recent successes suggest that an association should be established in Australia with oleic acid in Wagyu *longissimus dorsi* muscle through GWAS. If it is incorporated during the efficiency trials, BREEDPLAN will become the truly single stop evaluation for Wagyu.

**GeneSTAR**

Geneticist Don Nichol was the driver in Australia for GeneSTAR® Marbling which was launched in July 2000 with joint input from Beef CRC as the first DNA marker test for commercial use by Australian beef producers.

An association was found between number of tenderness markers and the measured tenderness. Although statistically significant, the total amount of phenotypic variation in tenderness accounted for by the GeneSTAR tenderness markers was only around 4% in temperate breeds and 6% in tropical breeds. While encouraging, it meant many more markers were required in both groups of breeds to account for a sizeable percentage of variation.

Nicol's evaluation for marbling did not find statistically significant (P>0.05) marker effect as either individual markers or as increasing ‘stars’. Marbling markers were not consistent for IMF, MSA marble score or AUS-MEAT marble score in any of the populations tested.

Net feed intake (NFI) is a measure of how much an animal eats relative to an expected amount for its weight and growth rate. The effect of increasing number of 'stars' was statistically significant for NFI (P<0.05) in the CRC temperate breed population, but not statistically significant in any other population.

GeneSTAR MVP using 56 markers replaced the initial 12 marker test. Pfizer claimed reliability values of 30, 26 and 39 percent for feed efficiency, marbling and tenderness, respectively in their promotions. However, marbling is the key focus for Wagyu producers so GeneSTAR was largely abandoned by the Wagyu industry in Australia.

Pfizer (later to be called Zoetis) persevered with other breeds and the 50K SNP test is incorporated in several countries into a BLUP analysis. The Zoetis i50K is a lower density (20,000SNP) with a lower cost version of the Zoetis HD50K, but with comparable accuracy.

A comprehensive array of 22 traits are tested by the Zoetis i50K and HD500K products: Calving Ease Direct *, Calving Ease Daughters, Birth Weight *, Gestation Length *, Weaning Weight *, Yearling Weight *, Final Weight *, Mature Cow Weight *, Milk *, Scrotal Size *, Days to Calving, Carcase Weight *, Eye Muscle Area *, Rib Fat *, Rump Fat *, Retail Beef Yield, Intramuscular Fat *, NFI (Feedlot), NFI (Post Weaning), Dry Matter Intake, Feedlot Daily Gain and Tenderness. The 14 traits that are incorporated into Angus BREEDPLAN have asterisks *.

Trends have recently been found of a positive association between marbling MVPs from published GeneSTAR results in a sales catalogue for Black Wagyu with ssgBLUP marble score EBVs. This indicates that some markers are presently common to both.

**Days on feed and efficiency when finishing**

The conundrum in the feedlot is to identify those Wagyu animals that are heavier than 550 kg that are laying marbling for which there is financial gain and those that are adding more backfat with an uneconomic conversion. Those that have grown on a controlled program through weaning and backgrounding will have the benefit of balanced muscle on a full frame. High Marble score EBVs for terminal sires for the feedlot are essential. Selecting for EMA using Breedplan EBVs has earned Scott de Bruin of Mayura Wagyu an additional $550 per carcass. High subcutaneous fat thickness (Rump fat EBV) will have a tendency to lay down backfat earlier and throughout so should be avoided from the feeding operation. Even during Yasufuku’s day, his role in increasing marbling without subcutaneous fat deposition was noted.
Wagyu Fullblood carcass data from a producer in Victoria were analysed. Dressing percentage was found to be negatively associated with rib fat thickness (R = -0.5). This aligns with the association between waste and subcutaneous fat thickness in Japan NARO 2008. The relationship between backfat thickness and feeding efficiency was evaluated using preliminary data that was shared from the ongoing Feed Efficiency Test at Kerwee Feedlot AWA conference 2017. Performance and net feed intake was recorded for progeny. Not all sires were identified in charts, but those that were, were evaluated against Rump fat EBVs. Results were shown of Feed Cost variances, but the association between Gross Margin variance with Rump fat EBV is charted alongside. The strongest association with Gross Margin was negative (R = − 0.93) with Rump fat EBV of sire, then second, but positive, was Marble score (R = + 0.54).

From such small numbers, these effects may prove to be speculative so the final report is eagerly anticipated. It is expected that consistent and moderate growth rate during backgrounding will ensure good conformation on feedlot entry, then expression of carcass traits and eating quality from efficient conversion during finishing are required to combine for optimum return.

Many independent components determine the efficiency of finishing Wagyu and they are in effect during different phases. Genetics has a considerable influence and environmental factors would affect different cohorts. However a genomic-wide association study in a controlled situation could provide a valuable $Index or EBVs for efficient Wagyu production.

Conclusions from genetic evaluation of eating quality

The influence of oleic acid in eating quality of Wagyu beef is acknowledged. No single test is available yet that determines the composition of the major fatty acids and the application of molecular genetic approaches may provide an opportunity for this. Melting point is another measurement of eating quality and samples were analysed by Dr Sally Lloyd of CY O’Connor ERADE Village Foundation. The Australian Branded Beef competition in 2015 published the results which included melting point from this laboratory. Melting point had an association with IMF% (R = +0.45) and there was a positive trend of IMF% with Judges’ Scores (R = + 0.35). There was no association between Melting point and Judges’ score. The lowest Melting point (28.3%) was recorded from a 5 year old pasture fed steer which had 19% IMF%. Further work may be required in evaluating the influence of polyunsaturated fatty acids, which are more abundant in pasture feeding than with grain feeding, because they have a lower Melting point than MUFA and SFA. Trials on Net Feed Intake are ongoing at Kerwee Feedlot. Until an efficiency EBV or $Index is launched, the wi CI will continue to be calculated during genetic evaluations of Wagyu breeding animal as it is proving to apply to today’s market requirements. However, today’s joining decisions
only hang off the hook in five years’ time so $Index require to be compiled with vision jointly with current market drivers. 
The 500K SNP is a single test that provides a single comprehensive breeding evaluation for multiple traits from single step gBLUP in Australia. Progress had been steady since digital imaging was incorporated until a decision was reported in April 2018 that scan data would be used again to assist with the estimation of marble score EBV. One sire had his predicted Marble score EBV dropped from +0.8 down to +0.4 because scanned data from 12 progeny had been included in the monthly “run”. Fortunately with the roll out of genomic and single step EBVs, the EBV has been established to be +1.0 and the scanned data is overruled. Prof Rob Banks has stated that the accuracy from scanned data for Wagyu is only 30%. The information that has been used in the BREEDPLAN analysis is written under the table. Genomics is written under Traits observed, and Scan progeny and Carcass progeny is written under Statistics. Caution is recommended when only Scanned progeny have been analysed for Marble score EBVs.
Similarly, unless progeny have been raised together, they should not be submitted as cohorts because this will also have an adverse impact on how the data will be analysed. The genomic EBVs can be obtained early in life and the best males and females can be retained for breeding. Conformation is checked again at weaning and candidate sires selected. The best will require carcass data from progeny for incorporation into ssgBLUP analysis. Prior to that, a minimum of 40 Fullblood progeny carcasses are needed from each candidate sire to be “proven” as trends only become evident from 20. Otherwise, 80 F1 progeny carcasses are required from crosses. The AWA tour to the Nick & Vicky Sher’s property in Victoria was told how they evaluate their own candidate sires from F1 progeny. During the farm tour, I asked Leigh Bradbury how many progeny results are required from each sire to get an evaluation and he answered 70. Fewer progeny would be sufficient when there is consistency amongst all of the dams. Unless 70 to 80 crossbred progeny have been obtained from any parent, any carcass claims that are made when marketing can only be considered to be speculative.

The Wagyu breed is usually finished with adequate marbling in order to receive a premium in the market and the quality of the beef is assured – especially when fineness of marbling is given second priority after IMF%. The third trait to be incorporated in selection is eye muscle area. Tenderness is rarely a limiting factor so there is no economic merit to select for the tenderness gene in the Wagyu breed when they are raised under conventional commercial conditions.
**Importance of nutrition for Wagyu eating quality**

My impression is that the Japanese underestimate the role that nutrition plays to bringing out the excellence from Wagyu beef. The Wagyu breed continues to marble beyond 30 months of age so feeding regimes evolved for finishing at this age or even beyond. On the other hand, most beef breeds in the western world are finished with short feeding.

Wagyu producers the world over try to raise their cattle like they are in Japan in an attempt to produce the best eating quality. I have been reading papers and books from Japan and have learnt how to translate written Japanese in the process. Tadaharu Kohno said at the recent Australian Wagyu Conference in Adelaide, Australia that Wagyu producers in Japan are reducing their target from producing A5 to A3 grade. With my understanding of the dependence on imported feed for the Japanese population and their livestock, and the high cost of locally raised beef, I was not surprised. I was anticipating that there would be less reliance on high energy feed because the question was being asked if IMF% would continue to be sustainable above 50%.

Whatever course the Japanese Wagyu industry takes, Wagyu producers in Australia should continue to produce Wagyu beef that meets the requirements of quality that each destination country prefers. Presently there is strong demand for Wagyu beef globally because of its availability and reputation, but customer preference should be determined.

A review is made on consumption in Japan, the reliance on imports and costs in Japan so that the drivers for production can be understood. Trade liberalization brought many changes to the agricultural market in Japan in the 1990s. Imports of cheaper, imported leaner beef posed a threat to the locally produced marbled traditional beef. Japanese Brown which had comprised 22% of the traditional beef herd was reduced to about 4% while production from the Japanese Black increased. Dairy steers had previously been marketed at 17 months of age, but they were retained up to 24 months of age and fed according to their physiology. Quality and carcass weight increased. When Japanese Black sires were crossed with Holstein cows, the carcass performance was virtually midpoint between the parents so even though inferior to the sire lines, more highly marbled crossbred beef became commercially available. F1 Holstein were fed to an average weight of 770kg. During 2016, approximately 240,000 Wagyu beef steers were processed together with almost 200,000 Holstein steers. Another 120,000 F1 Holstein steers were marketed with another 10,000 from other breeds.

After the tsunami wreaked so much damage on 11th March 2011, confidence in some agricultural produce from Japan was eroded. The number of cows, either lactating or dry, plus heifers counted on 1st February annually have declined progressively to 1.3 million in 2017. The number of cattle in the beef industry, including Holstein and F1 Holsteins destined for feeding decreased from 2011 to 2016 but a small increase was noted in Japanese beef and F1 Holstein herds.

With a high population density in Japan, 50 million tonnes of foodstuffs was imported in 2016 for human and livestock and this was just below half of the national requirement. 24 million tonnes of grain that was imported include 991,000 tonnes of rice. 15 million tonnes of corn is imported of which 11.4 million tonnes is for feeding livestock. 19% of total food consumption in Japan is by farm
animals that are, in turn, contributing to the food chain. Annual trends for Japanese consumption are illustrated below. Major foodstuff consumption, production and imports in 2016 are also charted.

Fish intake has declined by 4 kg per head over four years to 24.6 kg in 2016. This includes 8.5 kg that is fresh, chilled or frozen; whilst 60% of fish that is consumed is dried, salted or smoked. 50% of total fish consumed is imported.

Beef consumption is steady around 6 kg/head/day and only 38% by weight is produced in Japan as 752,000 tonnes is imported while 3,000 tonnes of beef are exported. Better use of natural resources in Japan for beef production are being evaluated but it is inevitable, in my opinion, that the quality will be compromised.

Pork consumption per head is double that of beef and annual imports of 1.3 million tonnes makes up 50% of total consumption. 35% of poultry consumption is imported.

Beef is an expensive source of protein with prices paid at the markets of ¥3,450 per kilogram from a Japanese Black steer that has graded A5. The average price for a steer is ¥3,103 per kilogram from an average weight of 480 kg in 2016. Cheaper imports of beef are relied on to ensure that a large portion of the population can afford to consume some. This was achieved through the import of 572.9 tonnes of beef at a cost of ¥641 per kilogram in 2017. Australia and USA compete for this and in 2014 when Australia’s FTA into Japan came into effect, it was expected that there would be market advantages over the USA but Japan importers passed this cost forward to the Japanese consumer, as the market was willing to pay a premium for US commercial beef over equivalent Australian beef.

Twice as much pork as beef is eaten in Japan. The wholesale price for 1st grade baconer weighing 77.4 kg averaged ¥529 across all markets. 932 tonnes of pork was imported at a cost of ¥526.83 per kilogram. 4.5 tonnes ham and bacon were imported at an average cost of ¥1,227 per kilogram.

Feeding programs in Japan are based on the physiology of each breed. Japanese Brown and Japanese Shorthorn have different growth rates and there is much variation between different Japanese Black strains in their respective prefectures. Studies on Japanese Black in major prefectures have shown that the difference in growth from each prefecture is related to growth hormone gene polymorphism. In feeding recommendations in Japan, the different beef breeds, strains and sexes are treated the same until reaching 200 kilogram bodyweight. Red Wagyu are heavier, and like in Japan, their marbling is lighter with a tendency to deposit heavier backfat so processing is at a lighter end point.

In Japan most crossbred beef is from Holstein cows and dairy has been a source of cheaper beef in Japan for a long time.
A different approach is made in Australia. Bodyweight is different, and so are the major base breeds for F1 production. I use a factor that is based on maintenance requirements of the core breeds in a feeding enterprise to determine the nutritive requirements for each 50 kg increment in each growth profile. When the requirements have been established, ingredients are considered with a view of attaining optimum quality and grades and then to temper them to local availabilities, resources and client’s desired end-point in the market.

There are several other considerations that can influence quality:

Beef flavour improves with higher oleic acid content and this can be influenced through genetics. Feeds that are high in oleic acid can also be incorporated.

Corn has highest oleic acid content amongst the cereals. Its amino acid fraction is inferior so needs to be topped up with other natural sources. Corn is high in starch which is an asset, but also requires to be balanced. The benefits of corn to flavour in beef are demonstrated in USA and the yellow fat colour needs to be managed. In Japan, straw is fed to eliminate the undesirable flavour from finishing on fresh pasture. Bran can be used to substitute some concentrates and flavour of the beef improves.

Although the grade of meat is determined by marbling (IMF%); work in Japan showed that extending the finishing period beyond an age of 29 months does improve meat colour, tightness and texture of beef, and the colour and the quality of fat. However, increasing the fattening period results in higher waste - such as visceral and subcutaneous fat – with a reduction in efficiency. The price grid will determine the carcass weight to obtain the maximum return for each operation. My analysis of carcass data against marble score EBV indicates that most cattle in Australia on conventional grain feeding are processed before they have attained their maximum genetic potential. This is a commercial reality.

Heifers deposit fat earlier than steers then slow down but have higher MUFA content. There is less flesh and the subcutaneous fat is thicker.

The temptation to boost early high growth to promote sales for seed stock should be resisted. Excessive energy cause deposits of fat and lead to ovarian malfunction or thyroid problems. Having said that, in Japan the first selection is on daily gain in the performance or ‘direct’ test. The levels of protein and energy were adjusted for candidate bulls from 2008 because of the adverse effects from excessive energy at an earlier age.

Wagyu are sold on the markets at ten months of age in Japan and this is usually when feeding commences. However, in order to improve efficiencies and to reduce total feed requirements (which are largely imported), feeding is commencing earlier. It is likely that if early gains increase significantly that there will be a decline in marbling grade and other carcass qualities but this option may be pursued in order to achieve sustainability.

There is a negative correlation between marbling and milk production in Black Wagyu. I have advocated either early weaning or supplementation until weaning in Australia for a while. A steady, but not excessive, live weight gain is required from birth, through backgrounding and during finishing. However, I have seen adverse effects on carcass qualities with Japanese Black that had high levels of feed versus moderate before 16 months of age, and similar trends in F1 in Australia with high and moderate weaning weights. Accordingly, I recommend moderate growth until in the finishing phase when optimum beef quality is desired. This also applies after early weaning. Excessive growth during backgrounding of F1 and Wagyu Fullblood are known to impair ultimate carcass quality in commercial feedlots in Australia. The ratio of body weight over body height gives an indication of fat deposition so it can be used for the determination of finishing potential.
Conclusions for nutrition

Early cell development of the embryo requires good nutrition to the pregnant dam, but must never be excessive because a healthy calf has to be delivered without dystocia. The first priority is stimulation of development of the rumen before weaning by the use of good quality roughage.

Secondly, steady growth from birth through to thirteen months of age is required for the skeleton and muscle framework to fully develop.

Energy levels should only be maximised from sixteen months through until processing. The desired carcass weight and grading specifications and age at time of processing determine desired growth rate from birth for each enterprise. Nutrition is set for each phase according to availability and cost so that best beef quality from ideal meat colour, tightness and texture of beef, and the colour and the quality of fat, marbling, minimum backfat and waste, thicker striploin and heaviest carcass is obtained.

Wagyu attain their unrivalled eating quality primarily from their ancestry which starts from the Fourth Eurochs, then continued unintentionally when raised for draught, and finally from selection for a few decades before the Foundations were exported from Japan. Secondly, appropriate feeding programs are required to provide the ultimate carcass. Every breed is unique. Wagyu should not be raised like any other breed, nor should any other breed be raised like Wagyu. A large export supply chain fed four thousand F1 steers for 100 days on a program designed to bring 2.4 kg daily gains from European-type cattle. The Wagyu gained about 1.35 kg/head/day as would be expected, but the grading of F1 carcasses only weighing 270 kg delivered a considerable loss.

Definitions

Akaushi. See Japanese Brown.

American Wagyu. Four bulls were imported from Japan to USA in 1976. They were crossed over local breeds and the fourth generation were classed as Purebreds with 93.75% Wagyu content. During the 1990s both in-calf heifers and bulls were imported from Japan, so 100% Wagyu (Fullblood) were bred. The minimum content that is permitted for beef to be labelled Wagyu in USA is 46%.

AUS-MEAT Eye Muscle Area (EMA). Eye Muscle Area is the area of the surface of the *M. longissimus dorsi* at the ribbing site and is calculated in square centimetres. Eye Muscle Area may be measured at the 10th, 11th, 12th or 13th rib.

AUS-MEAT Marble Score (MS). The AUS-MEAT marbling scores range from 0 (nil) to 9 (abundant) and are assessed based upon the amount of marbling present in the eye muscle and is assessed from the 5th to 13th rib on the carcase, depending on market. The range in Marble (IMF)% within each Marble Score is illustrated in the chart, but it invariably exceeds the minimum.
The IMF% by Marble Score in Australia is approximately half the IMF% for the same BMS in Japan. For example, Marble Score 4 in Australia has an average IMF of 15%, while BMS 4 in Japan has an average IMF that is above 40% Grose, 2011. Therefore, it is misleading when marbling scores in Australia are referred to as “BMS” in auction catalogues or sales promotions when they are really AUS-MEAT “MS”.

**Beef Marbling Standard (BMS).** Silicone resin models are used by graders for beef marbling to standardize the degree of marbling in different processing plants across Japan. The score is from 1 to 12 and there is minimum intramuscular fat percentage content for each score from 3. Score 1 is given when marbling is absent, and 2 is awarded when the minimum standard of 3 is not reached.

**Australian Wagyu.** Purebred embryos were imported from USA to Australia, but most Australian breeders build their herds with 100% content when the second wave of imports arrived in USA in the 1990s as females were included. The minimum content that is permitted for beef to be labelled Wagyu in Australia is 50%. 100% Wagyu content is called Fullblood Wagyu.

**Bayesian inference** (BayesB/R) is a method of statistical inference in which Bayes' theorem is used to update the probability for a hypothesis as more evidence or information becomes available. Bayes' theorem describes the probability of an event, based on prior knowledge of conditions that might be related to the event.

**Best Linear Unbiased Prediction (BLUP)** is the technology that incorporates multi-trait analysis procedures to produce estimates of breeding values (EBVs) for recorded cattle across a range of important production traits. Fixed effects of environment and genetics on observed phenotypic values are estimated simultaneously using BLUP and, therefore, genetic differences between herds are accounted for.

**Black Wagyu.** Numerous export consignments of Japanese Black were exported from Japan to USA. After quarantine periods were completed a number of them were exported to Canada and Australia while many remained in Australia. The Tajima, Itozakura, Kedaka and some Fujiyoshi are the major strains. Wagyu populations are raised globally in at least 35 countries.

**BMS.** See Beef Marbling Standard.

**Cohort.** A cohort or contemporary group consists of animals raised under the same management conditions.

**English.** Spelling has mainly been Australian English which resembles the original British English and differs from American English.

**Estimated Breeding Value (EBV)** is the genetic merit for each trait. EBVs are expressed as the difference between an individual animal’s genetics and the genetic base to which the animal is compared. EBVs are reported in the units in which the measurements are taken. On average, half of the EBV will be passed on to the animal’s progeny because the other half will pass from the other parent.

**Expected Progeny Differences (EPDs)** provide estimates of the genetic value of an animal as a parent. Specifically, differences in EPDs between two individuals of the same breed predict differences in performance between their future offspring when each is mated to animals of the same average genetic merit.
Genomic Best Linear Unbiased Prediction (GBLUP or gBLUP) is a method that utilizes genomic relationships to estimate the genetic merit of an individual. For this purpose, a genomic relationship matrix is used, estimated from DNA marker information.

Japanese Black. There are four beef cattle breeds in Japan – Japanese Black, Japanese Brown, Japanese Shorthorn, and Japanese Polled. The high levels of marbling in beef produced by Japanese Black cattle has led to this breed comprising the greatest share of Japan’s Wagyu cattle population. Each prefecture is responsible for the beef husbandry in its jurisdiction so distinct strains have evolved. Tajima in Hyogo originated from Naka-doi line and Kumanami-line, the Fujiyoshi-line from Shimane and Kedaka-kei and Eikō-line from Tottori and Kagoshima. Properties of the various strains are very distinct.

Japanese Brown. The Japanese Brown is the second most common domestic beef breed in Japan despite a reduction from 22% to 4% of the Wagyu population. Comprised of two isolated sub-breeds, Kumamoto and Kochi, each possessing a different gene pool. Simmental and Korean Hanwoo were crossed with native cattle in Kumamoto and Kochi, and Devon were crossed in Kumamoto before the Japanese Brown breed evolved. The Japanese Brown breed is also called Akaushi in Japan.

Pedigree BLUP (PBLUP). See Best Linear Unbiased Prediction (BLUP).

Predicted Breeding Value (PBV) is the genetic merit for each trait and comparisons are made within prefectures. In Japanese literature, both PBV and EBV have been translated. See Estimated Breeding Value.

MSA Marble Score. MSA marbling scores are used to provide a finer scale than the AUS-MEAT scores. It is assessed based upon amount as well as distribution of the marbling within the eye muscle. Each MSA marbling score is divided into tenths for grading, creating a score range from 100 to 1,190 in increments of 10.

P8 fat thickness. Fat depths may be measured manually using a cut and measure knife or electronically at the P8 site using a Hennessey Grading probe. Excess or deficiency of subcutaneous fat is undesirable. Some processors of Wagyu impose a penalty for fat depth lighter than 12mm and it is heavier when less than 6mm at P8 site. A penalty applies for depth exceeding 31mm and it is heaviest for P8 fat thickness exceeding 41mm.

Rib fat thickness. Rib fat is used in MSA grading as both a minimum requirement for grading and as a prediction input. The 3mm minimum standard aims at reducing temperature variation through the carcase muscles during chilling. A small eating quality improvement also occurs as rib fat increases from 3mm–18mm and this is more significant in breeds that do not exhibit much marbling. Accordingly, in Japan, subcutaneous fat thickness has a negative effect on yield estimate score.

Red Wagyu. Japanese Brown cattle that were exported from Japan are either called Red Wagyu or Akuishi. They were only selected from the Kumamoto strain of Japanese Brown so there is no Kochi strain Japanese Brown outside Japan. Red Wagyu have never exceeded 4% of the Wagyu population in Australia but they have a stronger following in USA, the southern Americas, and they were fashionable for a while in South Africa.
**Subcutaneous fat thickness.** Rib fat thickness is the measured depth of subcutaneous fat over the quartered rib site between the 5th and 13th ribs. Rib fat thickness may vary between sites and typically increases towards the head (5th rib). Rib fat is a better indicator of yield than the P8 site. It is measured when the carcass is chilled and quartered, as opposed to P8 fat being measured on the hot carcass on the slaughter floor.

**USDA beef marbling grades.** Prime beef is produced from young, well-fed beef cattle. It has slightly abundant to moderate marbling. Choice beef is high quality, but has less marbling than Prime. It has at least a Small amount of marbling, and can be modest or medium. Select beef is very uniform in quality and normally leaner than the higher grades. It is fairly tender, but because it has less marbling, it may lack some of the juiciness and flavour of the higher grades. It has at least a Slight amount of marbling.

**References and further reading**


AUS-MEAT, AUS-MEAT Beef and veal chiller assessment language.


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