# The relationship between marbling and sensory traits

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*Abstract.* Relationships between marbling and sensory traits were examined. The low and variable relationship between marbling and tenderness could occur via a number of different mechanisms, although because of interrelationships between sensory traits the relative contribution from the different mechanisms are difficult to quantify. In an attempt to minimize this confounding the effect of marbling (chemical fat percentage) on juiciness and flavour scores was examined, after adjustment for shear force. Analyses showed a curvilinear relationship between flavour and juiciness scores, which tended to plateau at 15 to 20% chemical fat. Differences between breeds in flavour and juiciness scores at the same shear force and chemical fat percentage were evident and were independent of animal age. In contrast, differences in flavour and juiciness scores between markets and different finishing systems appeared to be age related, when compared at the same shear force and chemical fat percentage.

## Introduction

Although marbling of beef is an important trait in a number of beef markets, the relationship between marbling level and palatability of beef is not clearly defined. Palatability of beef can be described as a function of tenderness, juiciness and flavour and is generally measured using one, or a combination of objective and sensory measurements. The former includes shear force, compression and adhesion measurements, which all describe specific dimensions of texture. Perry *et al.* (2001a) showed that these objective measurements were well related to sensory tenderness, although they are by nature rather simplistic measures and do not take into account the complex interactions that occur with flavour and juiciness dimensions during the eating process.

Sensory evaluation is performed by either a trained, or consumer (i.e. untrained) taste panel. A trained taste panel is skilled in independently scoring the different dimensions of palatability, whereas scores from consumer panel are more variable and generally the correlations between the different sensory dimensions is high. These high correlations between the different sensory dimensions complicate the interpretation of the relationships between the different sensory traits and carcass traits, such as marbling. This paper reviews some of the proposed mechanisms by which marbling impacts on palatability. There is less information on the relationship between flavour and juiciness traits and marbling and this aspect was investigated using data from the Cooperative Research Centre (CRC) and Meat Standards Australia (MSA) program.

## The impact of marbling on palatability

A perception common to both the meat production/processing and food service industries is that higher marbling gives rise to more tender beef. However examination of the literature shows that the relationship between marbling and tenderness is low and variable, with some studies showing a small positive association, whilst others have failed to report any significant trend (e.g. Dikeman1996). After reviewing a number of studies, Dikeman (1987) concluded that marbling accounted for approximately 10 to 15% of the variance in taste panel tenderness scores. However as pointed out by Dikeman (1996), although the direct relationship between marbling and tenderness may be low and variable, it does provide an assurance of tenderness and it is used in this role in a number of grading schemes (NLSMB 1995).

Millar (1994) discussed a number of mechanisms by which marbling could impact on tenderness. They include a change in bulk density with increased marbling fat, the increased lubrication effect of higher intramuscular fat levels and the effect of increased intramuscular fat on the connective tissue toughness. The low and variable relationship between fatness and tenderness is in accordance with fat (which is low density), simply diluting the higher density, heat denatured protein. Therefore a higher percentage of intramuscular fat simply results in a lower density steak, which requires less resistance to bite through. The lubrication effect relies upon the higher fat levels in marbled meat stimulating salivation and giving the perception of increased juiciness of meat whilst chewing. Beef with a higher intramuscular fat content will also sustain the feel of juiciness in the mouth, as well as impacting on beef flavour, given that the species specific flavours are contained in fat (Hornstein and Wasserman 1987). The effect of marbling on connective tissue toughness was on the basis that marbling fat is deposited in the perivascular cells, within the perimysium connective tissue. Therefore as marbling level increases the connective tissue toughness decreases and the meat is more tender. As discussed by Millar (1994) the exact mechanism by which marbling impacts on tenderness is difficult to define and given the complex structure of meat it is likely that all the above mechanisms operate to varying degrees. Experimentally it would be a difficult task to unravel the relative contribution of these mechanisms to changes in tenderness.

A theory popular with the food service sector is that marbling provides an insurance against the negative effects of overcooking (Smith and Carpenter, 1974). The argument is that fat conducts heat at a slower rate than lean and this acts to protect and insulate the muscle fibres against the shrinkage and denaturation that occurs as meat is exposed to high cooking temperatures. Therefore highly marbled beef would be expected to be both more tender and more juicy than lowly marbled product if cooked to a higher degree of donenesss. This was investigated in a CRC study by Rymill *et al.* (1997) where steaks across a range of marbling scores were cooked to rare and well done endpoints and then sensory tested. The authors found no evidence of an interaction between marbling and doneness on taste panel tenderness and juiciness scores, which does not support the theory that high intramuscular fat levels are beneficial to eating quality when steaks cooked to a well done end-point. They concluded that degree of doneness was considerably more important in producing tender and juicy steaks than was intramuscular fat percentage.

## The relationship between intramuscular fat and flavour and juiciness scores in grilled steaks

As mentioned previously the high correlations between sensory dimensions make it difficult to examine the effect of one sensory trait in isolation from the others. As an example of the high correlations between consumers scores, correlations between sensory traits for data in Table 1 ranged between 0.83 to 0.98, which meant that simple relationships between the different sensory traits and other variables, such as marbling, were confounded. In other words, the relationship between flavour and marbling in part reflected changes in tenderness. To minimize this confounding with sensory tenderness, the relationships between flavour and juiciness traits and marbling were examined after adjusting for shear force. By including shear force in the statistical model as a covariate, much of the confounding between tenderness and other sensory dimensions was removed.

*Data:* As part of the CRC straightbred and crossbred programs, the anterior half of the striploin was divided into objective and sensory blocks. An objective block (approximately 15cm) was frozen at 1 day post-mortem and subsequently tested for shear force and chemical fat percentage (Perry *et al.* 2001b). The remainder was vacuum packed and submitted to Meat Standards Australia (MSA) where it was aged for 14 days prior to trimming and cutting into grilling steaks for subsequent sensory testing using the MSA protocol (Polkinghorne *et al.* 1999). There were a total of 3,613 samples available from both the CRC straightbred and crossbred programs that had complete data for live animal, carcass, laboratory and sensory measurements.

*Experimental design:* The design for the CRC programs have been described in detail by Upton *et al.* (2001). Briefly, pedigreed weaner calves from contract matings were delivered to backgrounding properties twice a year (i.e. two cohorts). Cattle from each cohort were allocated to treatments to be finished on pasture or grain for slaughter at three market endpoints (domestic, Korean or Japanese carcass weights). Within a cohort/treatment sub-class all cattle were killed when the mean live weight reached the target slaughter weight. Within the data set there were several kills where carcasses were not stimulated and samples appeared to be cold-shortened (i.e. low sensory scores and high shear force). These kills have been excluded from other meat quality analyses, but for this study they were included since they increased the range in tenderness, and consequently the adjustment for shear force was more effective. As these kills were not randomly distributed across all fixed effects there was the potential to bias the estimation of these effects. Another potential shortcoming of the analysis was that flavour and juiciness scores, measured at 14 days ageing, were adjusted for shear force, measured at 1 day of ageing. Therefore the resultant adjustment between sensory scores and chemical fat percentage was confounded by the changes in the sensory traits associated with ageing striploin from 1 to 14 days.

*MSA sensory testing:* The MSA tasting protocol has been described by Polkinghorne *et al.* (1999). Briefly, consumer groups were recruited from a broad range of socio-economic backgrounds to participate in consumer taste panels. Consumers were used only once. The protocols for preparation of grilling samples have been described by Gee *et al.* (1998). Sensory samples were trimmed of all epimysium and fat and five 25mm steaks were cut. Grill steaks were cooked on a Silex griller to a medium degree of doneness. At each tasting session, a consumer was presented with a total of 7 grilled half steaks, over a 35 minute interval. Consumers were asked to score each sample for tenderness, juiciness, flavour and overall liking. The scoring sheet comprised four 100 mm lines, anchored with the words very tough/very tender for tenderness, very dry/very juicy for juiciness and extremely dislike/extremely like for both flavour and overall acceptability. Each sensory score was the mean of 10 individual consumer scores.

*Analysis:* Mixed models were used to examine the relationships of juiciness and flavour scores with chemical fat percentage, after adjustment for shear force. The models contained terms for shear force (linear and quadratic terms), chemical fat percentage (linear and quadratic terms), the interaction between shear force and chemical fat percentage and fixed effects for breed, market, finish and sex with random terms for cohort and kill. Non-significant covariates and interactions ($P>0.05$) were deleted from the model and the final models are presented in Table 2. As the significance of a number of the fixed effects on flavour and juiciness (adjusted to the same chemical fat percentage and shear force) appeared to be related

**Table 1.** Means, variance and range for sensory scores (at 14 days ageing), shear force (at 1 day of ageing), chemical fat percentage and animal age from 3,613 grilled striploins.

| Trait | Mean | STDEV | Range |
|---|---|---|---|
| Sensory scores | | | |
| Tenderness | 51.17 | 15.21 | 5.9 - 89.0 |
| Juiciness | 52.88 | 11.22 | 10.7 - 87.0 |
| Flavour | 52.9 | 12.62 | 14.0 - 88.0 |
| Overall liking | 52.29 | 12.96 | 9.1 - 90.0 |
| Shear Force (kg) | 5.01 | 1.72 | 2.12 - 18.1 |
| Chem fat% | 3.34 | 1.85 | 0.30 - 15.36 |
| Animal Age (days) | 715.6 | 166.2 | 343 - 1308 |

to age, the analyses were re-run with age as a covariate.

*Results and Discussion:* Means, variance and the range of sensory traits and carcass measurements are presented in Table 1. The variation in sensory scores was large with a range of approximately 80 units on a 100 point scale. Similarly there was a nine fold range in shear force, with the upper shear force at 18kg. Chemical fat percentages were skewed towards the lower levels with a mean of 3.3%, but did range up to 15% for some samples.

Tables 2 and 3 shows F ratios and regression coefficients for the final juiciness and flavour models. The F ratios showed much of the variation in flavour and juiciness was related to shear force, which indicated that in part, adjustment of juiciness and

**Table 2.** F ratios for the effects of animal age, shear force, chemical fat percentage (linear and quadratic terms), breed, finish, market and sex, (adjusted for random terms cohort and kill) on juiciness and flavour scores of grilled striploin steaks.

| Independent Variables | df | Not adjusted for age: Juiciness | Not adjusted for age: Flavour | df | Adjusted for age: Juiciness | Adjusted for age: Flavour |
|---|---|---|---|---|---|---|
| Covariates | | | | | | |
| Animal Age | | | | 1/3507 | 2.06 | 9.91 |
| Shear force | 1/3508 | 185.29 | 249.55 | 1/3507 | 185.93 | 252.34 |
| Chem fat% | 1/3508 | 47.19 | 56.08 | 1/3507 | 48.27 | 58.91 |
| $(\text{Chem fat\%})^2$ | 1/3508 | 4.94 | 9.82 | 1/3507 | 5.21 | 10.68 |
| Fixed effects | | | | | | |
| Breed | 16/3508 | 12.64 | 11.34 | 16/3507 | 12.27 | 11.78 |
| Finish | 3/3508 | 2.77 | 4.97 | 3/3507 | 0.81 | 0.22 |
| Market | 2/3508 | 4.75 | 7.43 | 2/3507 | 1.41 | 0.61 |
| Sex | 1/3508 | 0.92 | 2.55 | 1/3507 | 0.81 | 1.95 |

df - numerator/demoninator degree of freedom

Significant F ratios (P<0.05) are bolded

flavour traits for shear force achieved the aim of the analysis. Table 3 showed that as shear force increased (i.e. samples became tougher) juiciness and flavour scores decreased. However after adjusting for shear force there were still strong effects of chemical fat percentage on both sensory juiciness and flavour scores. As shown in Figure 1 there was a positive decreasing curvilinear relationship between adjusted flavour and juiciness scores with chemical fat percentage. Points of inflexion for the curvilinear functions were at the limits, or outside, the range of the data, at 19 and 14% chemical fat for juiciness and flavour scores, respectively. The author is not aware of other studies that have quantified the shape of the relationship between juiciness and flavour and chemical fat percentage, after adjusting for a measure of tenderness. The implication for Australian consumers is that if young animals are processed in a system where myofibrillar toughness is controlled, juiciness and flavour scores as a function of chemical fat percentage will tend to plateau at the higher levels of chemical fat for beef served as grilled steaks.

It is of note that even after adjusting for shear force and chemical fat percentage there were significant differences

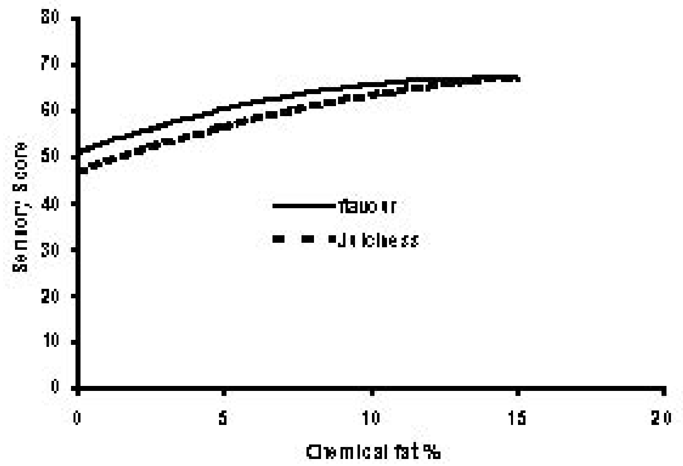


**Figure 1** The relationship between flavour and juiciness scores as a function of chemical fat percentage in grilled striploins, adjusted to a shear force of 5.0kg

r and juiciness, due to breed, finish and market. breed effects are not tabulated, the tropically adapted d crosses had juiciness and flavour scores which were nits lower than the *Bos taurus* breeds and crosses, me shear force and chemical fat percentage. As , breed effects on juiciness and flavour scores were ent of the age adjustment.

/location effect indicated that cattle raised on northern had juiciness scores which were up to five sensory er than cattle finished on either southern pasture, or ts (Table 3). Similarly for flavour, northern pasture

**Table 3.** Regression coefficients for the effects of animal age, shear force, chemical fat percentage (linear and quadratic terms), and least square deviations for finish, market and sex, (adjusted for breed and the random terms, cohort and kill) on juiciness and flavour scores.

| Independent Variables | | Not adjusted for age | | Adjusted for age | |
|---|---|---|---|---|---|
| | | Juiciness | Flavour | Juiciness | Flavour |
| Intercept | | 54.64 | 59.22 | 58.97 | 67.52 |
| | | (9.77) | (8.79) | (10.24) | (9.18) |
| Animal age | | na | na | -0.006 | -0.012 |
| | | | | (0.004) | (0.003) |
| Shear force | | -1.57 | -1.66 | -1.58 | -1.67 |
| | | (0.12) | (0.11) | (0.12) | (0.11) |
| Chem fat% | | 2.27 | 2.28 | 2.31 | 2.34 |
| | | (0.33) | (30) | (0.33) | (0.30) |
| (Chem fat%)$^2$ | | -0.06 | -0.08 | -0.06 | -0.08 |
| | | (0.02) | (0.03) | (0.02) | (0.03) |
| <u>Fixed effects</u> | | | | | |
| Finish | FN | -1.12 | 0.60 | -1.16 | 0.48 |
| | FS | 0.07 | 1.51 | -0.39 | 0.59 |
| | PN | -4.76 | -2.86 | -3.52 | -0.49 |
| | PS | 0.00 | 0.00 | 0.00 | 0.00 |
| | | (2.71) | (1.91) | (2.82) | (2.00) |
| Market | | | | | |
| | Dom | 3.76 | 3.35 | 2.61 | 1.11 |
| | Kor | 0.00 | 0.00 | 0.00 | 0.00 |
| | Jap | -0.14 | -0.11 | 0.28 | 0.72 |
| | | (1.51) | (1.07) | (1.56) | (1.17) |
| Sex | H | 1.92 | 2.24 | -1.84 | 2.07 |
| | S | 0.00 | 0.00 | 0.00 | 0.00 |
| | | (2.00) | (1.40) | (2.05) | (1.48) |

na - not applicable
FN, FS, PN, PS indicate cattle were feedlot finished in the north, feedlot finished in the south, pasture finished in the north and pasture finished in the south respectively
Dom, Kor and Jap refer to Domestic, Korean and Japanese slaughter weights which were 220, 280 and 320 kg carcass weight, respectively. H refers to heifers; S refers to steers.

finished cattle had lower scores than feedlot cattle (finished in either the north or south), or cattle finished in the south on pasture. The market effect showed that after adjustment for shear force and chemical fat, carcasses slaughtered at export weights (ie Korean or Japanese slaughter weights) had flavour and juiciness scores which were approximately three units lower than cattle slaughtered at domestic weights. When age was included in the juiciness and flavour models, finish/location and market effects became non-significant (Table 2, P>0.05), indicating that in the unadjusted analyses, the northern pasture finished cattle were less juicy and flavorsome because they were older.

One of the often quoted attributes of feedlot finished beef is the more desirable flavour and juiciness (Muir *et al.* 1996). Although not tabulated, this was initially examined in a model which were only adjusted flavour and juiciness scores for the fixed effects and shear force. These models showed that in the south (where mean slaughter age of the pasture and feedlot treatments were within 50 days of age), flavour scores from feedlot carcasses were three units higher than pasture finished carcasses (P>0.05). A similar trend was evident for juiciness, with a two unit advantage to feedlot carcasses, although it failed to reach significance (P=0.35). However when feedlot and pasture treatments finished in the south were compared at the same shear force and level of chemical fat percentage there was no difference in flavour scores (Table 3). This indicated that it was the higher chemical fat percentage in feedlot finished animals that conferred the advantage in flavour. In a review of the effects of pasture versus grain feeding effects on beef quality, Muir *et al.* (1998) concluded that when compared at the same fatness or carcass weight the majority of experiments showed little difference in flavour due to grain feeding.

The inclusion of age in the model for juiciness was not significant (Table 3, P>0.05), although it had the effect of reducing the finish/location and market effects. Other studies have generally reported that juiciness was not affected by age (Arthaud *et al.* 1977, Riley *et al.* 1986 and Powell 1991).

The intensity of beef flavour increases with age, although as a consumer flavour score it is negatively associated with age (Lawrie 1976). In the present study the age effect on flavour (adjusted for shear force and chemical fat percentage) was also negative, indicating that at the same chemical fat percentage and shear force, older animals had a less desirable flavour score. If chemical fat and was removed from the flavour model, the regression coefficient for age as a function of flavour was still negative (P<0.05, -0.006), although it was half the magnitude than before. This indicated that although chemical fat percentage has a positive effect on flavour and fat percentage increased with age, it was not sufficient to cancel out the negative relationship between flavour and age, evident when adjusted for both chemical fat and shear force.

*Conclusion*: As MSA is introduced nationally it is likely that much of the variation in tenderness consequent from production and processing factors will be addressed. Under this scenario it is likely that flavour and juiciness scores will become more important to beef consumers. These results suggest that if myofibrillar tenderness is controlled, marbling will become an important determinant of flavour and juiciness in grilled steaks for Australian consumers. However under this scenario the gains in flavour and juiciness scores will tend to diminish at the higher marbling levels. The MSA data suggests that if tenderness is controlled the relationship between flavour and juiciness with chemical fat will plateau between 15 to 20% chemical fat. To place this in a practical context, a 15% level of chemical fat would be equivalent to a AUSMeat marble score 4.

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