Does nutrition affect the eating quality of beef?

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Summary

In this paper we have discussed the results of two major studies of the effect of finishing nutrition on the quality of beef, and the relationship between marbling and palatability as determined by Australian consumers in testing by Meat Standards Australia. Grain finishing of cattle resulted in a small but consistent increase in both tenderness, measured objectively, and palatability. Increasing intramuscular fat content increased the probability of a higher MSA grade, as assessed by consumers, which in turn was correlated with increased juiciness and/or flavour, rather than with tenderness.

Introduction

Consumer studies have clearly identified consistency of eating quality of beef as a problem in Australia. In this regard tenderness, and its effect on overall palatability, is the major factor in consumer dissatisfaction, although juiciness and flavour also contribute to palatability.

The nutritional and environmental history of an animal may have an important impact on the intrinsic eating quality of the meat. This can be a direct effect on the muscle tissue, for example on the connective tissue matrix. It can also result from differences in intramuscular fat content which is an important trait that is affected by grain versus pasture finishing, the level of nutrition and by the age of an animal at a particular slaughter weight. Intramuscular fat content (marbling) is important in the beef grading schemes of both Japan and the USA (USDA 1989).

Under adverse environmental conditions these effects may be accentuated. The contrast between finishing cattle on extensive pasture systems and finishing cattle in a feedlot using a grain based ration, is an example of differing environments which might affect intrinsic meat quality.

This paper presents data on the tenderness and palatability of grain vs. pasture fed beef, derived from the research program of the Co–operative Research Centre for the Cattle and Beef Industry (Beef CRC) and from consumer research conducted by Meat Standards Australia (MSA).

Material and methods

The core cattle project of the Beef CRC

The data presented in this paper come from the 'straightbreeding' program, which has been described in detail by Robinson (1995). Briefly, it involved purebred Angus, Hereford, Shorthorn, Murray Grey, Brahman, Belmont Red and Santa Gertrudis steers and heifers which, after weaning, were grown out (backgrounded) on pasture prior to finishing on either pasture or in a feedlot. The British breed animals were all backgrounded and finished on the New England Tablelands of NSW. Animals from the tropically adapted breeds were born in Queensland and, post–weaning, divided into two groups within sire, one of which was backgrounded and finished in Queensland (northern) and the other on the New England Tablelands (southern). Cattle from both pasture and feedlot finishing regimens, from both environments, were grown out to three slaughter weights (400 kg, 520 kg, and 600 kg) to produce carcases suitable for the domestic, Korean and Japanese markets, respectively.

In an attempt to minimise pre–slaughter stress cattle were not handled for 3 days prior to trucking. Cattle were slaughtered through commercial abattoirs and most carcases were electrically stimulated using low or high voltage. The tenderness of the meat was assessed objectively by measuring the Warner Bratzler shear force (peak force) and the compression values on cooked samples from the striploin (*M. longissimus dorsi,* LD) at 1 day post–mortem (Bouton *et al.* 1972). Intramuscular fat percent was measured in the LD of northern animals by solvent extraction (AOAC 1990), and in southern animals by near infrared spectrophotometry using a prediction equation based on solvent extraction. Comparison of the two methods showed no consistent bias.

The effect of nutrition during the finishing phase of growth on the objective tenderness (peak force and compression) and intramuscular fat percentage of the LD was tested using a model with stimulation, finishing regimen, market, breed, location and the interactions between feed, market category, location, and breed fitted as fixed effects. Sire, herd of origin and kill (within market, location and feed) were fitted as random effects. Non–significant interactions (P>0.05) and age at slaughter if P>0.05 were sequentially deleted. The analyses for both the measures of tenderness were run with and without the intramuscular fat percentage of the LD as a covariate, to test the effect of intramuscular fat on any relationship between the fixed effects and tenderness. Data were available for 4126 animals. These analyses were repeated on the data available from the subset of animals tested by MSA.

Meat Standards Australia

The palatability of the meat from a subset of the animals, from both feeding regimens and both locations described above, has been determined using the consumer testing protocol developed by Meat Standards Australia (Polkinghorne *et al*. 1999). The data presented here are for striploins aged for 14 days and grilled according to standard MSA procedures. For each animal a total of 10 consumers were asked to evaluate the tenderness, juiciness and flavour and overall liking of cooked steaks , using a 100–point scale for each attribute. These results were then combined into a single meat quality score using weightings of 0.4, 0.1, 0.2 and 0.3 for tenderness, juiciness, flavour and overall liking, respectively. The 10 consumer scores were then clipped of the highest and lowest 20% and averaged to produce a CMQ4 score, where the higher the score the more palatable the meat. The effect of nutrition during the finishing phase of growth on this CMQ4 score was analysed as described above for objective measurements.

Using data on grilled striploins from the MSA database (Polkinghorne *et al*.1999), which includes commercial as well as CRC animals, separate analyses were done on the association of AUS–MEAT marbling score with the distribution of animals between the MSA palatability grades, as assessed by the consumer taste panels, and between AUS–MEAT marbling scores and the sensory dimensions for tenderness, juiciness and flavour within the MSA grades.

Results

The effect of finishing nutrition on tenderness and intramuscular fat

Figure 1 shows least square means for compression for grain and pasture finishing regimens, within market category, adjusted for breed, location (northern vs. southern), sire, herd of origin and day of kill (within market, location and feed). At each market weight the animals finished on grain had 0.19 (± 0.03) kg lower mean values for compression (were more tender) than those finished on pasture (P <0.001).

Table 1 presents least square means for tenderness measurements and chemical fat percentage for each feed x location sub group, adjusted for stimulation, breed, market, sire and kill within finish, market and location. Grain finished animals had 0.30 (± 0.12) kg lower peak force and 0.19 (± 0.04) kg lower compression values than equivalent animals finished on pasture (P<0.05). Peak force and compression measurements for northern finished cattle were higher than for those finished in the south (P<0.001). Within market category, age at slaughter significantly affected peak force (P<0.05) but not compression (P>0.05). The magnitude of the age effect was small (0.1kg per 100 days of age), but it reduced the significance of the feed effect from 0.009 (Table 1) to 0.08, and the magnitude of the effect to 0.2 kg (± 0.12). Age at slaughter did not alter the effect of feed and location on compression.

When adjusted for intramuscular fat percentage, the magnitude of the difference between pasture and grain finished animals was reduced to 0.16 kg (P<0.001) for compression and 0.21 kg (P>0.05) for shear force. Intramuscular fat itself was 1 ± 0.117 % higher in grain fed compared to pasture fed carcases (P<0.001).

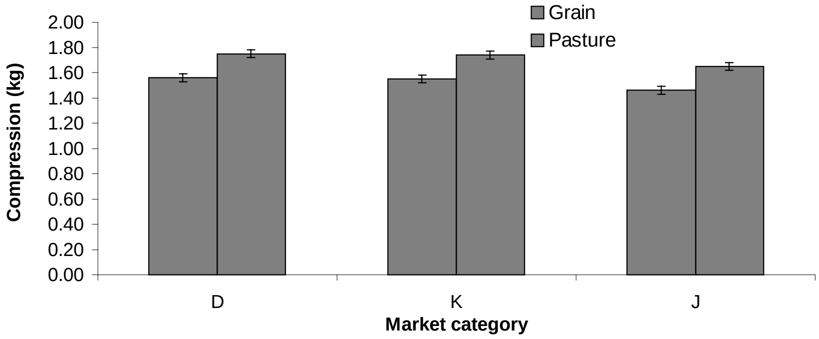

Figure 1 Compression least square means (kg) for pasture vs. grain finished animals, within D (Domestic), K (Korean) and J (Japanese) market categories.

Compression values decreased by 0.03 kg and peak force decreased by 0.09 kg for each increase of 1% in intramuscular fat (P<0.001).

The above analyses were repeated on the subset of animals tested using consumer taste panels by MSA. Table 2 shows predicted means for palatability and chemical fat for this subset of animals tested (n = 1373), adjusted for the same terms as the data in Table 1.

There was no significant effect of finishing regimen (grain vs. pasture) on peak force (P>0.05), but there was a difference between peak force measurements from northern and southern animals (P<0.05). With compression the reverse was the case. Pasture fed animals had higher compression values (tougher) than grain fed animals (P<0.001), with northern and southern finished animals having similar values within each feeding regimen (P>0.05). This effect of feed on compression was similar to that found in the larger data set. Age at slaughter within market had an effect on compression but not on peak force. However the magnitude of the effect was small (0.01 kg per 100 days increase in age) and adjusting for age had no effect on the significance levels of either feed or location on compression.

The objective measurements refer to samples which were tested one day post–mortem whilst the sensory results refer to samples tested after ageing these samples for 14 days. Therefore the latter includes effects for the inherent tenderness of the sample, plus the changes that occurred during ageing. The palatability scores (CMQ4) were lower for pasture fed animals than grain fed animals when they were finished in the north, but there was no difference for those finished in the south. This pattern was similar irrespective of whether the measurements were adjusted for chemical fat. For every 100 days increase in age at slaughter the CMQ4 decreased by 0.5 (P<0.05). If not adjusted for age within market category, the interaction between feed and location was not significant (P = 0.075). Animals finished in the south had higher palatability scores than those finished in the north.

Table 1 Peak force, compression and chemical fat in the striploin for cattle finished on pasture or grain in two environments (n = 4126).

	Location		Significance (P)	
	Northern	Southern	Feed effect	Location effect
Peak force (kg)				
Grain	6.10 ± 0.221	3.34 ± 0.144	0.009	0.001
Pasture	6.46 ± 0.275	3.66 ± 0.159		
Compression (kg)				
Grain	1.72 ± 0.079	1.56 ± 0.042	0.001	0.03
Pasture	1.98 ± 0.095	1.73 ± 0.051		
Chemical fat (%)				
Grain	3.85 ± 0.301	4.67 ± 0.192	0.001	NS
Pasture	2.92 ± 0.373	3.48 ± 0.214		

Table 2 Objective tenderness, palatability (CMQ4 score) and chemical fat determinations of meat from the LD muscle for the subset of cattle tested by MSA (n = 1373).

	Location		Significance (P)		
	Northern	Southern	Feed effect	Location effect	Feed x location effect
Peak force (kg)					
Grain	5.89 ± 0.427	4.54 ± 0.310	NS	0.02	NS
Pasture	6.51 ± 0.598	4.74 ± 0.597			
Compression (kg)					
Grain	1.67 ± 0.023	1.67 ± 0.016	0.001	NS	NS
Pasture	1.85 ± 0.030	1.80 ± 0.027			
CMQ4					
Grain	52.10 ± 2.06	59.30 ± 2.67	NS	0.001	0.001
Pasture	46.30 ± 1.40	61.10 ± 2.41			
Chemical fat (%)					
Grain	3.63 ± 0.232	3.78 ± 0.163	NS	0.001	NS
Pasture	3.10 ± 0.303	2.80 ± 0.294			

The effect of marbling on palatability

MSA consumer research has provided data on the role of marbling fat in the palatability of beef as evaluated by Australian consumers. Table 3 shows the effect of AUS–MEAT marbling score on the distribution of animals between the MSA grades as assessed by the consumer taste panels. The meat was from low *Bos indicus* content carcases which had been hung by the Achilles tendon and aged for 14 days prior to cooking as a grill and served to consumers. A higher marbling score increased the probability of a striploin being assessed as being in a higher grade (CMQ4 score was increased).

Table 4 shows correlations between marbling score and the sensory attributes of steaks from the striploin, within the different MSA grades. There appeared to be no relationship with tenderness but the correlation coefficients between marbling and both juiciness and flavour increased from no–grade to the 5–star category.

Discussion

The results of the CRC program show that, as determined by objective measurements on 4126 animals, the meat of cattle finished on grain was slightly but significantly more tender than that of equivalent animals finished on pasture. This effect could have been caused by an increase in intramuscular fat content, a direct effect of diet on the muscle tissue, or to a combination of both. However the difference in intramuscular fat for the two finishing regimens did not account for all of the pasture versus grain effect on shear force, and had little impact on compression values. Published studies suggest a direct effect on connective tissue, whereby feeding high–energy, intensive, diets increases the solubility during cooking of heat–labile connective tissue (Miller 1994). If this were so, differences in compression values (which largely reflect the connective tissue component of meat toughness) between feeding regimens should be consistent within environments. This was the case in this study. It should also be kept in mind that the two different feeding regimens almost certainly result in differences in growth rate, particularly when pasture conditions are poor, which may in turn affect the structure of collagen within muscles, and the relationship between the connective tissue matrix and the myofibres. This in turn would affect meat tenderness. This may explain the significant effect of location of finishing on tenderness, with the meat from animals finished in the south being more tender than that of animals finished in the north. Consumers also found southern finished beef more palatable than northern finished product when assessing 14 day aged LD steaks. However they distinguished between grain and grass finished product only in northern finished animals, where the difference between growth rates on pasture and grain could be expected to be greater than in the more benign southern environment. In this smaller data set the difference between compression values for northern and southern finished animals, evident in the larger data set, was not apparent, but the difference in compression between grain and grass finishing systems was similar for both locations.

The relationship between intramuscular fat content and tenderness has been widely studied but no consistent relationship has been established. Its role in the palatability of meat has been discussed by Savell and Cross (1988) and Miller (1994). Most studies have been done in the USA and these show that increasing marbling decreases the variability in the palatability of beef. At the marbling scores found in Australian product (AUS–MEAT score 0–3, intramuscular fat below 7%), intramuscular fat content probably explains only a minor proportion of the variation in tenderness. The MSA data presented here show that as marbling increased the palatability of the meat increased, although even at the higher levels of marbling approximately ten percent

Table 3 The effect of marbling score on the distribution of animals between the MSA grades assigned by the consumer taste panels.

	AUS–MEAT marbling score			
MSA Grade	**0**	**1**	**2**	**3**
5–star	2	5	8	20
4–star	23	32	56	53
3–star	39	42	27	13
No grade	37	21	9	13

Table 4 Correlations between AUS–MEAT marbling score and consumer sensory score, within MSA grades, for grilled striploin steaks aged for 14 days.

	Sensory attribute			
MSA Grade	**Tenderness**	**Juiciness**	**Flavour**	**No. of cattle**
5-star	– 0.18	0.36	0.24	167
4-star	0.02	0.20	0.20	1322
3-star	0.04	0.12	0.11	1646
No grade	0.08	0.09	0.09	1007

of the steaks tested failed to grade as satisfactory. Therefore whilst marbling improves palatability it is not a guarantee, and a proportion of failures can still occur. The MSA data also show that as MSA grade increased the correlation between marbling and the meat quality attributes of juiciness and flavour increased, but that between marbling and tenderness remained close to zero.

These studies show small but consistent benefits in improved tenderness and increased palatability result from grain finishing, especially if the pasture finishing alternative were under adverse conditions. However it is not possible to say whether the benefits were due directly to difference in feed and its effect on intramuscular fat or muscle structure, or a consequence of other changes induced by differences in feed, such as higher or consistent growth rates. The effect of age within market category on tenderness traits was not consistent between the data sets studied here and did not account for all of the feed or location effects. The effect of growth path on meat quality is being investigated by the CRC, but it is not a simple question. Overall growth rate from birth to slaughter must be compared with growth rates and set backs during distinct periods of an animal's growth path, such as during the periods of pre– and post–weaning, backgrounding and finishing.

References

Association of Official Analytical Chemists (1990). Official Methods of Analysis, 15th Edition. AOAC, Inc.

Miller, R.K. (1994). Quality Characteristics. In: *Muscle Foods – Meat, Seafood and Poultry Technology* pp, 296–332 (eds. D.M. Kinsman, A.W. Kotula and B.C. Breidenstein). Chapman and Hall, New York .

Polkinghorne, P. Watson, R., Porter, M., Gee, A., Scott, J. and Thompson, J. (1999). Proceedings of the 45th International Congress of Meat Science and Technology, Yokohama, Japan.

Robinson, D (1995). Design of the CRC straightbred genetics experiments. *Proceedings of the Australasian Association of Animal Breeding and Genetics* **11,** 541–545.

Savell, J.W. and Cross, H.R. (1988). The role of fat in the palatability of beef, pork, lamb. In: *Designing Foods: Animal Product Options in the Marketplace*. National Academy Press, Washington D.C.

USDA (1989). Official United States standards for grades of carcase beef. Agriculture Marketing Service, USDA, Washington D.C.