Final Report M.233 - Library Copy.

MEAT RESEARCH CORPORATION PROJECT M.233

"COMPUTER DATABASE SEARCH OF FACTORS AFFECTING MARBLING IN BEEF"

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TERMS OF REFERENCE

The project will utilize a computer database to search for abstracts describing research undertaken on beef quality, particularly non-genetic factors effecting marbling. Important areas revealed by the search will then be analyzed and information will be compiled into a booklet which will be made available to researchers in Australia.

A report will be presented to Meat Research Corporation.

EXECUTIVE SUMMARY

This project and a related project (M.182) were aimed at searching past and current research in Japan and North America for technology that may assist us in designing production systems to improve the quality of beef sold to Japan. The projects concentrated on non-genetic means of improving marbling or intramuscular fat. In project M.182, interviews with researchers in Japan was carried out and a report has been provided. The current project undertook a database survey of the scientific literature which captured mostly research undertaken in North America.

M.182 "Meeting carcass specifications for the Japanese market" has reported on research in Japan aimed at improving meat quality and returns to domestic producers. The conclusions of that report were that there was opportunity to achieve quality grades 2 and 3 (equivalent to domestic dairy steer beef) with existing Australian genotypes. Project M.112 is in the process of identifying sires within breeds with appropriate carcass merit. At no time was it considered possible to achieve Wagyu quality without Wagyu genetics. This conclusion has now been shown to be incorrect by evidence presented in the current report. A Japanese based company is achieving high quality grades on a regular basis (up to grade A5) and is achieving just under Wagyu prices on the wholesale spot market with air freighted carcasses. These carcasses are produced with Australian genotypes, fed in Australia and slaughtered at a local works. Photographs and official Japanese grading sheets obtained in Japan are presented in the Appendix. Enquiries have revealed that these carcasses achieving high grades in Japan are being fed using traditional Japanese methods in Australia for up to 500 days.

The high grade end is not a large segment of the Japanese beef market, however there will be opportunities for smaller operators to service that sector. There will be increased costs associated with the longer feeding to achieve the higher quality and obviously the prices achieved on the spot market in Japan for this product need to be returned to the producer incurring this increased cost. Producers need to be more aware of the value of their product and its competitors in Japan to successfully market. The fact that such high quality is being achieved indicates that we can better service the B2-B3 sector of the market which the McKinsey report indicated was the major opportunity for the Australian industry.

The search of the scientific literature undertaken in this report pointed to opportunities for small improvements in marbling or intramuscular fat but gave no indication as to how the above improvement was being achieved. Continuing inquiries are revealing some interesting results including the concept that overhealthy cattle do not marble well.

Small improvements in marbling are possible through the use of protected lipids, ionophores, corn or maize as the main source of grain and by avoiding the use of hormonal growth promotants during the final finishing phase (last 80-100 days or so). Most of these improvements are NOT independent of carcass composition and therefore incur penalties in feed efficiency and retail yield.

Slaughtering cattle as they approach two years of age can result in carcasses grading USDA Choice following as little as 150 days grainfeeding. This 150 days grainfeeding is the minimum required for consumers in Japan to consider the product Grainfed according to the recently released report of the MRC project 'Sensory Market Analysis of Fresh Meat in Japan'. Grainfeeding for up to 250 days at younger ages resulted in lower grades and lighter carcass weights. This indicates that there is an optimum age for marbling which is around 2 years.

Other meat characteristics important to Japanese buyers appear to be highly correlated to marbling and length of time of grainfeeding and or age. These characteristics include meat texture, firmness, fat softness and luster and meat color. There is very little in the scientific literature on these characteristics. More work needs to be done in this area firstly to understand how buyers discriminate these attributes and secondly how they affect consumer important factors. Consideration needs to be given to including these other quality factors into existing Australian meat description systems.

Level of unsaturation of fat is important through its influence on fat quality. A high level of unsaturation is desirable and this increases with age and extended grainfeeding. C18.1 appears to be the most important fatty acid here with C16 being an undesirable fatty acid. These fatty acid profiles are important to flavor, taste and perhaps odor.

Independent work of a commercial nature has indicated that Japanese graders are significantly tougher than Australian graders. Carcasses graded 4 for marbling in Australia by AUSMEAT personnel are sometimes downgraded 1 marbling score when graded in Japan by JMGA personnel. There is also a significant affect of temperature on marbling grade achieved. Grading at colder temperatures results in intramuscular fat being more visible and thus grades achieved higher. The practice of grading in Australia prior to boning means that on heavy carcasses suitable for Japan, temperature at the time of grading is 10-15 C. In Japan, following 40 hours chilling, the temperature is much lower at 0-4 C. This means that, compared with Japan, we are grading conservatively and therefore undervaluing our product. An objective system using chemical fat content would therefore be desirable. An investigation of chemical fat content of meat graded under different situations (Australia Vs Japan) is recommended.

An interview with executives of the Japanese Meat Grading Association revealed that fat quality (softness and luster), meat texture, meat tightness and muscle water content are characteristics not adequately described by the grading system but that meat buyers looked for. Differences in these characteristics accounted for price differences between Wagyu and Holstein carcasses of the same grade. These differences seem to be due to the production system used for Wagyu and Holstein beef where Wagyu are fed for longer and slaughtered at older ages.

CONCLUSIONS

Through both genetic and non-genetic means, improvements in meat quality can be achieved that will allow us to target both the middle (Dairy quality grades 2 and 3) and upper (Wagyu quality grades 3 and 4) sectors of the Japanese market.

Best bet production systems for the middle sector include slaughtering at around 2 years of age following relatively short periods of grainfeeding (150 or so days). Diets should include protected lipid, ionophores, Maize or corn as the main source of grain and minimal necessary processing. Use of Hormonal Growth Promotants should be restricted to the growing phase and these treatments should be withdrawn in the final phase of finishing. Any factors reducing feed consumption should be eliminated.

Areas of opportunity remain in understanding the partitioning of fat between different depots and whether this can be manipulated by changes in nutrient supply through rumen protection technology.

Regarding targeting the upper end of the market, investigations of current practice should proceed to determine what techniques are being used by operators achieving high grades. The fact that there are now Wagyu genes in Australia, North America and New Zealand reinforces this need.

Opportunities for research lie in protected lipid technology and the potential for manipulation of fatty acid profiles (and the influence this has on flavor, taste and cooking odor) which are important in the high quality sector of the market but not so important in the middle quality sector. Understanding those other quality factors (including fat softness and luster, meat texture and meat tightness) not accurately described by the Japanese grading system, but understood by meat buyers and reflected in price is also very important.

INTRODUCTION

This project is part of an ongoing strategy to improve the quality of beef exported to North Asian markets. Other projects have included investigations of production systems and research in Japan in order to identify possible technologies applicable to Australia but currently used in Japan.

This project is to look more widely at technology and research, particularly into marbling in beef. A plethora of research has been undertaken in the USA where quality grading standards are dependent on the amount of marbling in the eye muscle. Databases including US research are therefore very important to this project.

The DIALOG information system was used to search for scientific references in the past 20 years that discussed research related to beef quality and in particular grade. A total of 704 references were found mostly from the USA with some from Japan, Australia and Europe. These references and abstracts were then indexed according to subject, alphabetically. The references were also scanned to determine those of most interest. References and papers of most interest were then obtained and analyzed to provide the following information.

A copy of the abstracts and index are now available from the MRC library.

FEEDING SYSTEM

Much has been said about the effect of pre feedlot entry nutrition on production and marbling in the feedlot. There is now strong evidence from a number of sources that body composition can be manipulated by nutritional means. Re-analyses carried out by Byers (1982) of much early data has shown that body composition can be manipulated to some extent by diet. In his paper, Byers proposed that there was an upper limit to protein deposition for any given animal and that this upper limit in Hereford steers fed a forage and grain diet was of the order of 100g of protein per day. This meant that as daily empty body weight gain increases, an increasing proportion is deposited as fat and a decreasing proportion is deposited as protein. The practical ramification for this is that cattle growing more slowly for longer, have more protein and muscle and therefore saleable meat than cattle of the same weight grown more quickly. Alternatively, cattle grown more slowly attain similar body compositions at heavier weights. The conclusions of his work were that "Restricted energy intake, larger mature size, and use of anabolic agents will divert energy to protein storage and will result in greater protein accumulation and less fat at any selected weight."

Certainly, Japanese feeding systems would appear to have embraced this concept for their Wagyu feeding systems although not for their Holsteins. Wagyu growth is restricted early by reducing energy intake, however finishing diets are high energy diets with limited roughage. This feeding system may therefore be used to improve yield and reduce fat laydown early, rather than to improve marbling as has been previously thought.

Evidence from other experimental work has shown that pre-feedlot entry treatments have very little if any effect on quality grade on exit from the feedlot although they had quite significant effects on lean meat yield related factors. Some interesting results are presented below.

Reference 1. Effect of 2 phase diet (low energy followed by high energy) vs constant high energy finisher diet on meat yield and quality at the same slaughter weight.

	High energy	2 phase
Age at slaughter (days)	455	474
Cold carcass weight (kg)	313	314
Eye muscle area (sq cm)	74.8	79.5
% edible meat	53.4	54.4

Comments: 2 phase feeding tended to reduce marbling although only marginally. Subcutaneous fat thickness was reduced on the two phase feeding. Eye muscle area and yield of edible meat were increased on the 2 phase feeding system compared with the single phase feeding system for cattle of the same weight.

Reference: Smith, S. H., Plimpton, R. F. Jnr., VanStavern, B. D., Parrett, N. A., and Ockerman, H. W. (1989). Journal of Animal Science, 67:2655.

Reference 2. Effect of backgrounding plus finishing vs direct finishing on body composition and carcass grades slaughtered at expected low choice grade.

	Direct finisher	Backgrounded & finished
Starting weight (kg)	260	257, (361)*
Final weight (kg)	468	561
Days fed	160	162, (119)
Hot carcass weight (kg)	231	337
Fat thickness (cm)	1.01	1.22
Eye muscle area (sq cm)	72.2	77.0
Marbling score	8.4	9.9
Quality grade	8.4	9.5

* Numbers in brackets refer to finishing ration.

Comments: Slaughter was undertaken when longissimus intramuscular fat was expected to be 4.5% which is equivalent to low choice quality grade. Marbling scores and quality grades indicate direct finished cattle where slaughtered a little earlier than they should have been. Final carcass weights for conventionally fed (backgrounded then finished) however were almost 50% heavier than cattle fed high energy diets to slaughter although there was little improvement in marbling or quality grade. The backgrounded and finished treatment is close to the current conventional system used in the USA.

Reference: Dikeman, M. E., Nagele, K. N., Myers, S. M., Schalles, R. R., Kropf, D. H., Kastner C. L. and Russo, F. A. (1985). Journal of Animal Science, 61:137.

Reference 3. Effect of different backgrounding treatments on production and carcass quality grades.

	High*	M/273	M/364	P/273	P/364
Growing phase (d)	66	79	173	133	201
Finishing phase (d)	163	160	111	156	101
Total days weaning to slaughter	229	239	284	289	302
Slaughter wt (kg)	476	476	486	486	480
Carcass wt (kg)	304	298	303	303	300
Dressing %	63.9	62.7	62.3	62.3	62.6
Fat thickness (cm)	1.4	1.4	1.5	1.5	1.5
Rib eye (sq cm)	77.4	74.5	73.9	73.3	72.1
Quality grade **	9.2	9.2	8.9	9.3	8.4

** Choice = 11 Prime = 14

* Treatments.

High; Cattle fed from weaning to 273 kg then to slaughter on a high grain finisher ration.
M/273; Cattle fed 50% concentrate ration until 273kg then a high energy finishing ration.
M/364; Cattle fed 50% concentrate ration until 364kg then a high energy finishing ration.
P/273; Cattle grazed wheat pasture until 273kg then a high energy finishing ration.
P/364; Cattle grazed wheat pasture until 364kg then a high energy finishing ration.

Comments: Cattle fed on a high plain of nutrition from weaning to slaughter (High, M/273, P/273) tended to have higher quality grades than cattle backgrounded to 364 kg. Although Rib Eye Area was greatest on the cattle fed high energy finishing diets from weaning to slaughter (suggesting higher meat yields), visceral fat was also highest. Rib dissection revealed no difference in composition between treatments.

Reference: Ridenour, K. W., Kiesling, H. E., Lofgreen, G. P. and Stiffler, D. M. (1982). Journal of Animal Science, 54:1115.

Reference 4. Effect of forage based and grain based diets on body composition at constant carcass weight.

	High grain	High forage
Average daily gain (kg/d)	1.46	1.06
Feed conversion ratio (kg/kg)	9.5	12.7
Fat weight per side (kg)	46.9	34.5
Muscle weight per side (kg)	109.0	118.0
Bone weight per side (kg)	24.6	28.0
Percent dissected fat	26.0	19.1
Percent dissected lean	60.4	65.3

Comments: Forage based diets (pelleted Lucerne) resulted in slower growth rates and poorer food conversion efficiency. They also resulted in higher levels of carcass protein and muscle at the same carcass weight and less fat. No measures of marbling or grade were taken in this experiment.

Reference: Price, M. A., Butson, S., and Makarechian, M.. (1984). Canadian Journal of Animal Science, 64:323.

Reference 5. Effect of grain finishing on marbling and intramuscular fat composition following 180 days pasture grazing.

	Grass fed	Short fed (56 d)	Long fed (112 d)
Marbling score *	3.8	8.6	12.2
Intramuscular fat composition (%)			
C 18.0	20.3	16.5	14.5
C 18.1	36.8	44.8	47.1
C 18.2	6.4	5.2	4.4
Total saturated fatty acids	48.7	43.8	41.3
Total unsaturated	51.3	56.2	58.7

Marbling score. Practically devoid = 5, Traces- = 7, Traces + = 9

Comments: Fat content and intramuscular fat composition was influenced by grain feeding following 180 days grazing pasture. Length of grain feeding improved marbling score and unsaturated fatty acid content of intramuscular fat. Flavor in taste panel tests were positively correlated with fatty acid C 18.1 and total unsaturated fatty acids and negatively correlated with saturated fatty acids. Cattle in this experiment were slaughtered at different weights.

Reference: Westerling, D. B., and Hedrick, H., B. (1979). Journal of Animal Science, 48:1343.

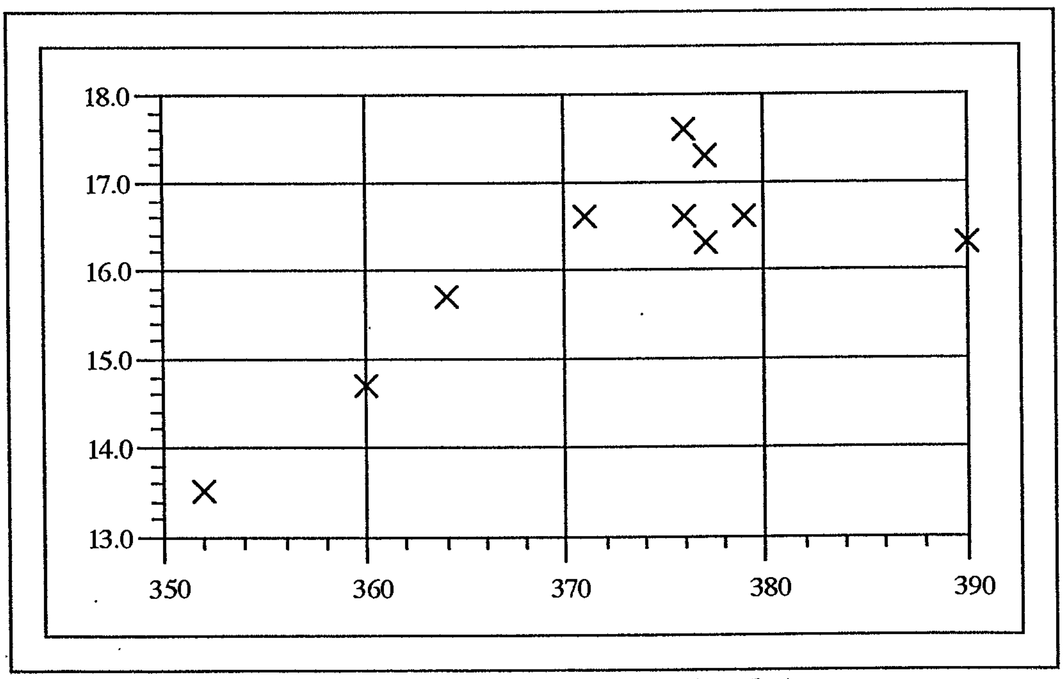
Reference 6. Effect of different diets on carcass weight and quality.

DIET *	CCS WT	FAT CM	MBLING**	EE%#
CS; CSM	360	1.01	14.7	7.3
CS; U; CORN	371	0.95	16.6	7.3
CS; U; CORN	376	1.00	17.6	7.9
CS; U; CORN; S	377	1.06	17.3	7.9
UCS; CSM	352	0.80	13.5	7.3
UCS; CSM; CORN	376	1.13	16.6	7.8
UCS; CSM; CORN:50%	364	0.94	15.7	7.0
UCS; CSM; CORN; S	379	1.10	16.6	7.1
BG; CORN	390	1.26	16.3	7.7
BG; CORN:50%	377	1.07	16.3	7.5

* CS= CORN SILAGE CSM= COTTON SEED MEAL U= UREA
CORN= CORN GRAIN S= SULPHUR UCS = UREA TREATED CORN SILAGE
CORN:50% = CORN GRAIN IN THE LAST 100 DAYS OF THE 200 DAY FEEDING.
** MARBLING. SLIGHT+=12 SMALL-=13 SMALL=14
SMALL+=15 MODEST-=16 MODEST=17 MODEST+=18
EE% is ether extract percentage in muscle dry matter. It is a chemical measure of fat content and therefore marbling.

Comments: Increased marbling was associated with increased grain in the ration. This was also related to increased weight thus increased marbling was closely related to carcass weight. See graph below. There appears to be no effect of diet itself apart from through increased weight of cattle and therefore carcass. Fatty acid composition of intramuscular fat was not significantly effected by diet.

Effect of increasing carcass weight on marbling



Final weight after 200 days feeding (kg).

Reference: Skelley, G. C., Edwards, R. L., Wardlaw, F. B. and Torrence, A. K. (1978). Journal of Animal Science, 45:1102.

Reference 7. Effect of length of grainfinishing on marbling and IM fat.

DAYS GRAIN FED	0	21	42	63
Marbling*	12	12	14	15
Quality grade**	17	17	18	19
Fat thickness cm	0.8	0.9	1.0	1.2
Intramuscular fat %***	12.5	11.2	15.8	19.5
Oleic acid (%FFA)	40.1	43	43.2	44.7
Stearic acid (%FFA)	19.4	18.9	17.5	15.2

* 11= slight 14 = small
** 17 = good 20 = choice
*** Intramuscular fat percentage is expressed as percent of dry matter.

Comments: Increasing time on concentrates increased marbling, grade and IM fat content. There was also a shift in fatty acid composition with an increase in oleic acid and decrease in stearic acid. No difference was observed in observations of a taste panel.

Reference: Dinius, D. A. and Cross, H. R. (1978). Journal of Animal Science, 47:1109.

Reference 8. Effect of ad lib vs limit feeding on efficiency and meat quality.

	AD LIB FEEDING	LIMIT FEEDING
Slaughter weight (kg)	587	572
Daily gain (kg/day)	1.35	1.25
Feed consumption (kg/day)	11.86	10.03
Feed/gain (kg/kg)	8.78	8.06
Marbling *	12.5	12.1
% Choice	61	42
SECOND EXPERIMENT		
Marbling	14.2	12.7
% Choice	95.8	62.5

* Marbling grades as for reference 7.

Comments: Full ad lib feeding resulted in a decrease in efficiency but improved marbling. Percentage of carcasses grading choice was more sensitive than marbling number.

Reference: Hicks, R. B., Owens, F. N., Gill, D. R. Martin, J. J. and Strasia, C. A. (1990). Journal of Animal Science, 68:233.

Reference 9. Effect of percent roughage in diet on efficiency and meat quality.

PERCENT ROUGHAGE	0	5	10	15
Average daily gain (kg/day)	1.34	1.52	1.57	1.53
Feed Consumption (kg/day)	8.58	9.00	9.12	9.24
Feed/gain (kg/kg)	6.41	5.93	5.81	6.05
Marbling **	5.12	5.21	5.19	5.14
% Choice	67.7	77.4	81.3	71.0
Condemned livers	58.1	54.8	62.5	71.0

** Slight = 4.5 Small = 5.5

Comments: Percent Choice was highly correlated with Average daily gain. Percent choice was more sensitive to diet changes than marbling score. Although there was a small difference between treatments in marbling, this may have been due to rate of gain effects as observed by other workers rather than roughage level.

Reference: Kreikemeir, K. K., Harmon, D. L., Brandt, R. T., Nagaraja, T. G., and Cochran, R. C. (1990). Journal of Animal Science, 68:2130.

Reference 10. Effect of backgrounding on production and carcass quality.

	NO BACKGROUNDING	BACKGROUNDED
Start weight (kg)	276	365
Slaughter weight (kg)	473	524
Days fed	127	90
Daily gain (kg/day)	1.59	1.80
Feed consumption (kg/day)	11.8	13.0
Feed conversion (kg/kg)	5.6	5.5
Marbling	Slight 86	Slight 77
Meat color	2.9	3.3

Comments: Backgrounding did not increase marbling. If anything, marbling at the same level of finish (same subcutaneous fat thickness) was the same, but in heavier weights than in non backgrounded cattle. This suggests that backgrounding would reduce marbling at the same slaughter weights.

Reference: Huffman, R. D., Williams, S. E. Hargrove, D. D., Johnson, D. D., and Marshall, T. T. (1990). Journal of Animal Science, 68:2243.

Reference 11. Effect of rate of gain during backgrounding on production and carcass quality.

BACKGROUNDING GAIN	LOW	MEDIUM	HIGH
Winter weight (kg)	239	233	239
Spring weight (kg)	269	273	292
Feedlot entry weight (kg)	343	338	346
Finish weight (kg)	526	528	541
Daily gain (kg/day)	1.64	1.70	1.74
Feed consumption (kg/day)	11.96	11.99	12.35
Gain/feed (kg/kg)	0.137	0.141	0.141
Quality grade	7.24	7.27	7.24

Comments: Rate of gain during the 200 day backgrounding period had no effect on efficiency in the feedlot (112 days) nor on marbling.

Reference: Lewis, J. M., Klopfenstein, T. J., and Stock, R. A. (1990). Journal of Animal Science, 68:2525.

Reference 12. Effect of 85 day backgrounding diet on feedlot performance and meat quality.

BACKGROUNDING DIET	CS*	CS:HMC	HMC
Backgrounding period			
Start weight (kg)	246	246	246
Daily gain (kg/day)	0.88	0.78	0.88
Feed consumption (kg/day)	5.9	4.7	4.1
Feed conversion (kg/kg)	6.7	6.1	4.7
End weight (@ 85 days)	321	313	322
Feedlot phase			
Final weight (kg)	496	489	494
Daily gain (kg/day)	1.48	1.50	1.47
Feed consumption (kg/day)	8.1	8.1	8.1
Feed conversion (kg/kg)	5.48	5.40	5.52
Quality grade**	3.25	3.25	2.83
Backfat (cm)	1.7	1.8	1.7
KPH fat (%)	3.4	3.6	3.4

* CS = Corn silage CS:HMC = Corn silage, high moisture corn HMC = High Moisture Corn. CS:HMC and HMC diets were limit fed to give same rate of gain as CS.
** Quality grade 2 = select, 3 = Low choice, 4 = Avge choice

Comments: Pre conditioning with grain only reduced marbling compared with pre conditioning with roughage (corn silage) or roughage plus grain. Performance and efficiency were not effected by backgrounding diet. A second trial confirmed the results of the first and quality grade was 3.26 with corn silage in the grower diet compared to 3.07 with high moisture corn as the grower ration.

Reference: Loerch S. L. (1990). Journal of Animal Science, 68:3086.

Reference 13. Effect of number of days on feed on marbling.

DAYS ON FEED	100	130	160
In weight kg	360	320	280
Marbling	slight	slight	small
Grade Choice%	32.3	32.7	47.7
Good%	58.8	56.4	37.7
Standard%	8.9	8.3	8.6
Comm/Util%	0	2.6	6.0

Comments: Marbling score (300-399 = slight, 400-499 = small) increased by 0.941 units per day and LD lipid content increased by 0.021 % per day on feed.

Reference: Tatum, J. D., Smith, G. C., Berry, B. W., Murphey, C. E., Williams, F. L., and Carpenter, Z. L. (1980). Journal of Animal Science, 50:833.

Reference 14. Effect of grass feeding, short grain feeding (49 days), long grain feeding (98 days) and forage feeding (98 days) on marbling.

FEEDING STYLE	GRASS	SHORT	LONG	FORAGE
Carcass weight	254	279	324	323
Marbling	Tr83	Sl56	Sm75	Sm49
Grade	Good03	Good54	Choice14	Choice03

Comments: Marbling and grade improved with grain feeding and days on feed, however this was also associated with increased carcass weights.

Reference: Harrison, A. R., Smith, M. E., Allen, D. M., Hunt, M. C., Kastner, C. L., and Kropf, D. H. (1978). Journal of Animal Science, 47:383.

Reference 15. Effect of different finishing regimes on meat quality and yield.

REGIME	A	B	C	D	E
LD fat%*	2.8	2.4	4.0	3.8	5.3
Retail product, kg*	217	225	208	208	198
Marbling*	7.76	7.35	9.45	9.38	10.13

* These results are adjusted to equal carcass weights of 300 kg. They are the average for the 2 biological types used in the experiment (large frame and small frame cattle).

Diet regimes.
A: Winter growing ration for 134 days (9.1 Mj/kg DM), grazing for 133 days, then a medium energy finishing ration for 98 days (11.9 Mj/kg DM).
B: Winter growing ration for 134 days (9.1 Mj/kg DM), grazing for 133 days, then a high energy finishing ration for 98 days (13.0 Mj/kg DM).
C: Forage ration (Corn silage and alfalfa haylage) for 315 days (10.0 Mj/kg DM).
D: Forage ration (Corn silage and alfalfa haylage) for 217 days (10.0 Mj/kg DM), then a medium energy finishing ration for 98 days (11.9 Mj/kg DM).
E: Medium energy finishing ration for 266 days (11.9 Mj/kg DM).

Comments: Low energy growing rations and grazing followed by short periods on finishing rations resulted in less marbling but higher retail product yields at the same carcass weight than higher energy rations including corn silage.

Reference: Smith, G. M., Crouse, J. D., Mandingo, R. W., and Neer, K. L. (1977). Journal of Animal Science, 45:236.

Reference 16. Effect of different finishing regimes on meat quality and yield.

FINISHING SYSTEM	WT*	GRADE	YIELD	LD FAT	LEAN
Calves	152	8.2	77.0	1.0	61.7
Yrlgs, lot fed 125 days	234	8.4	75.5	1.9	63.4
Yrlgs, lot fed 255 days	308	10.1	72.0	3.2	58.9
Yrlgs, lot fed 263 days**	271	9.6	-	-	-
Long Yrlngs grass fed	187	6.4	77.7	1.4	70.0
Long Yrlngs grass/grain	222	7.3	76.9	0.7	65.1
Long Yrlngs grass,130 d grain	315	8.9	73.7	2.8	62.3
2yo grass fed	317	7.6	75.4	2.0	57.6
2yo grass/grain	335	8.0	74.2	3.4	60.2
2yo grass, 98 days grain	385	11.2	72.6	3.9	56.5

* WT is cold carcass weight in kg.
** These yearlings were fed a silage diet for 210 days then grain for 53 days.
GRADE is USDA quality grade, Choice= 11, Low choice =10.
YIELD is weight of trimmed primals as % of carcass.
LD FAT is fat content of the longissimus muscle as measured by ether extract.
LEAN is lean content of the carcass as estimated by rib dissection.

Comments: Yearlings fed silage (210 days) followed by a short period on grain (53) graded as well as yearlings fed a full grain ration for 255 days, long yearlings grainfed for 130 days and 2 year olds grainfed for 98 days. Carcass weight for the silage fed group was lighter than the other groups. The silage used was a sorghum silage.

Reference: Bowling, R. A., Riggs, J. K., Smith, G. C., Carpenter, Z. L., Reddish, R. L., and Butler, O. D. (1978). Journal of Animal Science, 46:333.

Reference 17. Effect of age and dietary energy level on intramuscular and sub cutaneous fatty acid composition.

Cattle were weaned at 205 days of age and then slaughtered at 9, 12, 15, 18 or 24 months of age. Cattle slaughtered at 9, 12, and 15 months were placed directly on a medium or high energy content finishing ration. Cattle slaughtered at 18 or 24 months of age were backgrounded on a low energy ration before being placed on the high or medium energy finishing ration for,the last 140 days prior to slaughter.

AGE AT SLTR	9	12	15	18	24
Carcass weight(kg)*	134	183	207	242	317
Quality grade**	9.38	10.38	13.05	11.56	13.69
Marbling score***	4.50	9.12	16.50	12.31	18.19
Days on finishing ration	65	160	250	140	140

*Numbers quoted are for steers only. Bulls showed similar trends with lower quality grades and marbling scores.
**Quality grades 16=Prime, 13=Choice, 10=Good.
***Marbling scores 1=Devoid, 28=Abundant

Comments: Marbling and grade improved with age, however, age from 9 through to 15 months of age was associated with days on feed (high or medium energy finishing ration). Cattle slaughtered at 18 and 24 months of age were backgrounded on a low energy diet (gaining at about 0.5 kg/day) and this reduced marbling at similar carcass weights. Steers and bulls finished on high and medium energy finishing rations had quality grades of 12.00 and 11.09 respectively and marbling scores of 13.53 and 11.66 respectively. Carcass weights however were also effected by dietary energy level. There were minor differences in fatty acid composition at subcutaneous and intramuscular sites.

Reference: Clemens, E., Arthaud, V., Mandigo, R., and Woods, W. (1973). Journal of Animal Science, 37:1326.

Reference 18. Effect of slaughter weight, frame size (breed) housing and feed on carcass quality.

Small frame size (Angus) and large frame size (Holstein) cattle were fed to different slaughter weights in either a housed or standard feedlot using a high or medium energy finishing ration.

Comments: Marbling score, quality grade and rib eye area increased by 0.028 units, 0.027units and 0.10 sq cm respectively with each kg increase in carcass weight. Marbling score and quality grade were significantly effected by breed and carcass weight. In addition, the high grain diet increased quality grade slightly. Type of housing did not significantly influence any measures of meat quality.

Reference: Nour, A. Y. M., Thonney, M. L., Stouffer, J. R., and White, W. R. C. (1983). Journal of Animal Science, 57:1154.

FEED INGREDIENTS

There are many feed ingredients that have been suggested as having an influence on marbling or intramuscular fat. These ingredients fall into several categories being

Normal feeds (including different grains and roughages)
Additives (including fats and oils and other ingredients)
Rumen modifiers (including ionophores and other antibiotics)

Reference 19 . Effect of corn or grain sorghum in feedlot rations on meat quality and yield.

GRAIN TYPE	CORN	GRAIN SORGHUM
Feed conversion efficiency	8.2	8.3
Carcasses grading		
USDA Prime/choice %	63, 66*	55, 68
Good	35, 32	43, 31
Marbling scores	16.3, 16.15**	16.74, 16.60

*Where two figures are used, these represent different replicates in the experiment.
** Marbling score 16=Small plus, 17=Small

Comments: Carcasses from steers fed corn graded higher than those of steers fed sorghum, however, differences were only very small. Yield indicators suggested steers fed sorghum had higher meat yields.

Reference: Schake, L. M., Driedger, A., Riggs, J. K. and Clamme, D. N. (1976). Journal of Animal Science, 43:959.

Reference 20 . Effect of corn, triticale or wheat in feedlot rations on meat quality and yield.

GRAIN TYPE	TRITICALE	CORN	WHEAT
Avge daily gain kg/d	1.13	1.33	1.25
Daily feed intake kg/d	9.1	10.4	9.1
Feed conversion efficiency	8.02	7.81	7.24
Quality grade*	10.4	10.8	9.9
Marbling scores**	7.8	7.5	8.1
Shear force, lbs/in	25.3	20.2	24.6
Longissimus fat content %	3.41	4.56	2.67

*Quality grade 10=Good, 11=Good plus, 12=Choice minus, 13=Choice
** Marbling score 7=Small, 8=Slight, 9=Trace

Comments: A combination of quality and marbling fat measurements indicated that carcasses from steers fed corn were of higher quality. These measurements included quality grading, marbling scores, chemical fat% in the longissimus and shear force. Differences however were small. There were no significant differences between grain used on texture of marbling, color of lean and firmness or texture of lean. There were no significant differences in cooking loss, drip loss, flavor score, tenderness score or acceptability score. Fatty acid profiles of the longissimus were similar excepting for Myristic acid and a non significant difference in Oleic acid.

Reference: Reddy, S. G., Chen, M. L., and Rao, D. R. (1975). Journal of Animal Science, 40:940.

Reference 21. Effect of feeding protected fats and oils on feedlot performance and fatty acid composition.

Vegetable oils and tallow were protected by a protein/formaldehyde complex. The protected protein and lipid were then included in feedlot rations for cattle.

PROTECTED LIPID	NIL	15%O	30%O	15%T	25%T
Slaughter wt kg	417	408	419	432	399
Avg Daily Gain kg/d	1.36	1.29	1.38	1.51	1.20
Feed conversion	6.7	6.7	6.3	5.9	6.3
Carcass fat content %	26.5	29.8	32.9	31.1	30.3
Quality grade*	11.3	12.5	12.6	12.5	12.6

*Quality grade 11=good+ 12=choice- 13=average choice

Comments: Protected proteins and lipids increased the fat content of empty body gain and reduced both water and protein content of empty body gain. Performance and efficiency were to some extend effected although variably depending on product used and level of incorporation. Fatty acid composition of fat depots was altered with the use of protected vegetable oils and this change appeared to be complete within 50 days of the commencement of using the protected fat or oil. The use of protected lipid improved quality grade slightly at similar carcass weights.

Reference: Garrett, W. N., Yang, Y. T., Dunkley. W. L., and Smith, L. M. (1976). Journal of Animal Science, 42:1522.

Reference 22. Contribution of Acetate, Lactate and Glucose carbon to intramuscular and subcutaneous fat deposits.

Carbon found in fat depots can be derived from a number of compounds. Tissue culture techniques were used to determine whether or not there was a difference between fat cells from intramuscular and subcutaneous depots in their uptake of nutrients.
Comments: There was no observable difference in cell size or cell number distribution from steers of different ages or fed different diets. Fat cells from the subcutaneous site appeared more active in taking up precursors than intramuscular fat cells. In subcutaneous cells, acetate became less important with age and both lactate and glucose became more important. Acetate provided 70-80 percent of the acetyl units in fatty acid synthesis in subcutaneous fat cells. Acetates contribution in intramuscular fat cells was 10-26 percent. The authors concluded that as the tissues are biochemically different, the potential exists to manipulate fat deposition independent of marbling fat.

Reference: Smith, S. B., and Crouse, J. D. (1985). Beef Research, Progress Report No. 2. Roman L. Hruska U.S. Meat Animal Research Center, U. S. D. A. Agricultural Research Service.

Reference 23. Effects of dietary energy density on carcass composition and meat quality.

Over 1,800 cattle in 7 experiments were used to assess the effect of different dietary energy concentrations (altered by changing the grain to roughage ratio) on body composition and meat quality.

Comments: Higher energy rations increased daily gain, and improved feed conversion efficiency. Lower energy density rations led to increased protein deposition and retail yield in cattle at the same slaughter weight. Retail product yield or cutability was improved by 2-5%. When slaughtered at the same weight or rib fat percentage, cattle from higher energy diets had a slightly higher marbling score (less than one third of a degree of marbling).

Reference: Bennett, G. L. (1988). Beef Research, Progress Report No. 3. Roman L. Hruska U.S. Meat Animal Research Center, U. S. D. A. Agricultural Research Service.

Reference 24 . Effect of dietary fat sources on efficiency and meat quality.

A number of fat sources were included in feedlot diets to assess the influence of dietary fat on efficiency and meat quality.

FAT SOURCE	NIL	SOYOIL	TALLOW	YELLOW GREASE
Avge daily gain kg/d	1.42	1.54	1.50	1.59
Feed intake kg/d	8.90	8.91	8.67	9.13
Feed/gain	6.25	5.78	5.75	5.71
Marbling score	5.07	5.12	5.00	5.15
Choice %	62	79	62	79

Comments: The addition of fat sources improved efficiency but had no effect on quality grade or marbling score. In a second trial, soybean soapstock was also trialed. Tallow appeared to give better results than soybean soapstock.

Reference: Brandt, R. J., and Anderson, S. J. (1990). Journal of Animal Science, 68:2208.

Reference 25 . Effect of dietary Calcium soaps on efficiency and meat quality.

Protected lipid in the form of Calcium soaps were incorporated into feedlot rations to determine the effect of these on efficiency and meat quality.

CA SOAP LEVEL	0%	2%	4%	6%
Avge daily gain kg/d	1.46	1.49	1.39	1.25
Feed intake kg/d	8.4	8.2	7.8	6.9
Feed/gain	5.93	5.82	5.64	5.54
USDA quality grade	3.4	3.6	3.1	3.4

Comments: The inclusion of protected lipid in the form of Calcium soaps improved efficiency but had no effect on quality grade.

Reference: Ngidi, M. E., Loerch, S. L., Fluharty, F. L., and Palmquist, D. L. (1990). Journal of Animal Science, 68:2555.

Reference 26 . Effect of ionophores on efficiency and meat quality.

Ionophores (Monensin) was added to the ration to assess its effect on efficiency and meat quality.

MONENSIN	NIL	+
Avge daily gain kg/d	1.68	1.68
Feed intake kg/d	8.9	8.6
Feed/gain	5.32	5.12
USDA quality grade	3.05	3.28

Comments: Monensin improved efficiency and appeared to improve marbling and quality grade.

Reference: Loerch S. L. (1990). Journal of Animal Science, 68:3086.

Reference 27 . Effect of ionophores on efficiency and meat quality.

Laidlomycin proprionate (an ionophore) was added at various levels to assess its effect on efficiency and meat quality.

IONOPHORE LEVEL	0	6	9	12
Avge daily gain kg/d	1.20	1.31	1.28	1.31
Feed intake kg/d	10.6	10.7	10.5	10.3
Feed/gain	9.02	8.31	8.37	8.00
USDA quality grade	12.34	12.57	12.59	12.62

Comments: The inclusion of Laidlomycin proprionateimproved gain, efficiency and quality grade .

Reference: Spires, H. R., Olmsted, A., Berger, L. L., Fontenot, J. P., Gill, D. R., Riley, J. G., Wray, M. I., and Zinn, R. A. (1990). Journal of Animal Science, 68:3382.

Reference 28 . Effect of grain type, grain mixes, roughage levels and monensin usage on efficiency and meat quality.

A range of dietary strategies were used and investigated for their effects on efficiency and meat quality.

Comments: There was no difference between high moisture corn and dry rolled grain sorghum as the main grain source in its effect on marbling. Increasing roughage content from 0-9% tended to improve marbling. Dry rolled corn in diets appeared to produce better marbling than dry rolled grain grain sorghum. Wheat produced carcasses with intermediate marbling. Monensin tended to improve marbling in the absence of roughage.

Reference: Stock, R. A., Sindt, M. H., Parrott, J. C., and Goedeken, F. K. (1990). Journal of Animal Science,68:3441.

Reference 29 . Effect flake density in sorghum on efficiency and meat quality.

Grain sorghum was flaked to achieve different densities. The effect of this on efficiency and meat quality was investigated.

FLAKE DENSITY G/L	437	360	283
Avge daily gain kg/d	1.54	1.53	1.53
Feed intake kg/d	9.80	9.29	9.02
Feed/gain	6.37	6.06	5.92
Choice %	67	51.9	52.3

Comments: Decreasing flake density tended to improve efficiency and reduce quality.

Reference: Xiong, Y., Bartle, S. J., and Preston, R. L. (1990). Journal of Animal Science, 69:1707.

Reference 30 . Effect grain type and buffer use on efficiency and meat quality.

Flaked maize and sorghum were compared as the main grain types in a feedlot ration. Sodium bicarbonate was used as a buffer and the use of these components were tested for effects on efficiency and quality.

Comments: There was no difference between grain types or the usage of buffers on marbling. Rate of gain and efficiency were superior with steam flaked maize compared with sorghum. The use of a buffer improved rate of gain and feed consumption but did not effect efficiency.

Reference: Zinn, R. A. (1990). Journal of Animal Science, 69:1707.

MANAGEMENT

Reference 31 . Effect of shade and shelter on efficiency and meat quality.

Provision of shelter improved feed intake, daily gain and feed conversion efficiency compared with no shelter or confinement. Quality was effected to a small degree, however seasonal effects were much more significant.

Reference: Pusillo, G. M., Hoffman, M. P., and Self, H. L. (1991). Journal of Animal Science, 69:443.

Reference 32 . Effects of castration and implantation with hormonal growth promotants on meat traits in male cattle.

A range of male calves of different breeds was castrated using different techniques (emasculator and surgical), left intact or left intact and implanted with one of two dose rates of Zeranol, 36 mg and 72 mg. In a second experiment, bull calves were surgically castrated, left intact or left intact and implanted with 36 mg Zeranol. Two sites of implantation were investigated, in the ear, or in the scrotum.

Experiment 1.

TREATMENT	Castrated	Intact	Implant 36mg	Implant 72mg
Avge daily gain kg/d	0.91	1.18	1.41	1.41
Feed conversion	10.32	7.34	7.05	6.81
Hot carcass weight kg	366	410	417	429
Est retail product %	78.4	82.2	81.7	81.2
Marbling score*	9.3, 8.4**	6.6	6.4	6.3
Color of lean***	4.55	4.3	4.2	4.5
Texture of lean#	5.7	5.3	4.9	4.9

*Marbling score 5=Traces 8=Slight 11=Small.

** Where two values are quoted, there was a significant between castration technique (emasculator vs surgical).

***Higher lean color numbers are lighter in color.

Higher texture numbers represent finer texture.

Experiment 2.

TREATMENT	Intact	Castrated	Scrotal implant	Ear implant
Avge daily gain kg/d	1.32	1.00	1.18	1.18
Feed conversion	6.81	8.77	7.01	7.22
Hot carcass weight kg	346	316	332	339
Est retail product %	75.2	79.2	79.3	79.8
Marbling score##	8.4	6.2	6.6	5.7
Color of lean##	4.4	4.2	4.0	4.1
Texture of lean##	5.7	5.3	4.5	4.6

These values were not significantly different in experiment 2 but followed the trend shown in experiment 1.

Overall results

TREATMENT	Intact	Castrated	Implant 36 mg	Implant 72 mg
L dorsi fat %	2.2	3.1	2.8	2.4
Marbling score	6.5	8.1	6.8	5.9
Warner-Bratzler (lb)	8.8	7.9	9.5	10.4

Comments: Entire and implanted cattle had lower marbling and lower fat levels compared with castrated steers. Rates of gain and efficiency were lower for castrates. Method of castration did not have a significant effect.

Reference: Gregory, K. E., Ford, J. J., Seideman, S. C., and Hays, W. G. (1985). Beef Research, Progress Report No. 2. Roman L. Hruska U.S. Meat Animal Research Center, U. S. D. A. Agricultural Research Service.

Reference 33 . Genetic correlation between marbling and other production traits.

In assessing a large number of breeds representing a wide range of types, the authors showed a strong negative genetic correlation between retail product yield and marbling. Also of interest was a table describing Quality Grade and marbling score descriptions with chemical fat content.

BREED CROSS	MARBLING	USDA CHOICE %
Chianina	8.3	24
Limousin	9.0	37
Brahman	9.3	40
Gelbveih	9.6	43
Sahiwal	9.7	44
Simmental	9.9	60
Maine-Anjou	10.1	54
Tarentaise	10.2	60
Charolaise	10.3	63
Brown swiss	10.4	61
Pinzgauer	10.8	60
South Devon	11.3	76
Hereford-Angus	11.3	76
Red Poll	11.5	68
Jersey	13.2	85

MARBLING SCORE	QUALITY GRADE	% FAT
Fat free		0
Practically devoid	Standard	0.7
Traces	Standard	2.2
Slight	Select	3.7
Small	Choice	5.2
Modest	Choice	6.7
Moderate	Choice	8.2
Slightly abundant	Prime	9.7
Moderately Abundant	Prime	11.2
Abundant	Prime	12.7

According to a previous report M.182, Standard and utility were thought to have 3% or less fat, Select 5.2%, Choice up to 9.5% and Prime 10% or better. There are some minor differences compared with this table.

Reference: Gregory, K. E., Cundiff, L. V., and Koch, R. M. (1988). Beef Research, Progress Report No. 3. Roman L. Hruska U.S. Meat Animal Research Center, U. S. D. A. Agricultural Research Service.

Reference 34 . Effects of hormonal treatment on heifer beef.

Heifers were left intact or ovariectomized, then either immunized against estradiol, implanted with trenbolone acetate, or untreated. Production levels and carcass quality measurements were taken following a feedlot phase.

Comments: Immunizing against estradiol in combination with implanting with trenbolone acetate appeared to be superior to either treatment on its own in improving gain and efficiency. There was no significant difference between treatments on any meat quality characteristics. All treatments averaged modest levels of marbling.

Reference: Crouse, J. B., Schanbacher, B. D., Cross, H. R., Seideman, S. C., and Smith, S. B. (1988). Beef Research, Progress Report No. 3. Roman L. Hruska U.S. Meat Animal Research Center, U. S. D. A. Agricultural Research Service.

Reference 35 . Effects of various implant treatment on steer beef.

A range of commercially available implants were tested on steers either finished in a feedlot following a period on grass, or in a feedlot situation.

TREATMENT	CONTROL	RALGRO	SYNOVEX-S	COMPUDOSE
Daily gain kg/d	1.07	1.22	1.16	1.15
Feed intake kg/d	9.60	10.42	10.15	10.12
Feed conversion	7.87	7.18	7.25	7.43
Marbling score	5.05	4.90	4.62	5.07
Choice %	86	82	69	82

Comments: Feed efficiency was significantly improved with all implants. Carcass quality was significantly reduced only by the Synovex-s treatment.

TREATMENT	Nil	Ralgro	Synovex-s	Compudose	Finaplex	Forplex	Revalor
Daily gain kg/d	1.21	1.24	1.29	1.30	1.23	1.32	1.34
Marbling score	4.94	4.78	4.79	4.83	4.87	5.02	4.49
Choice %	82	53	72	83	83	83	44

Comments:The results show a trend for increased efficiency to be accompanied by reduced marbling and therefore grade. The only effect that was statistically significant was the reduction in marbling and quality grade associated with the use of Revalor.

Reference: Schanbacher, B. D., and Brethour, J. (1988). Beef Research, Progress Report No. 3. Roman L. Hruska U.S. Meat Animal Research Center, U. S. D. A. Agricultural Research Service.

Reference 36. Effects of various implant treatment and spaying on heifer beef.

A range of commercially available implants were tested on speyed and intact heifers.

TREATMENT	Intact nil	Intact SynvxH	Spayed	Spayed SynvxH	Spayed SynvxS
Feed:gain	6.36	6.24	6.59	6.10	5.62
Marbling score*	6.1	5.2	5.7	4.6	5.2
USDA grade**	8.1	7.0	7.7	6.4	7.2

*Marbling score 4=slight 5=small 6=modest

**USDA grade 6=Select+ 7=Choice- 8=Choice

Comments:Implantation tended to reduce quality grades and marbling scores.

Reference: Garber, M. J., Roeder, R. A., Combs, J. J., Eldridge, L., Miller, J. C., Hinman, D. D., and Ney, J. J. (1991). Journal of Animal Science, 68:1469.

SUMMARY

Using a computer data base search, 700 references which used "meat quality", "beef quality" in conjunction with "beef" or "cattle" were captured. The vast majority of these references described scientific research carried out in the USA with a small number describing work in Japan. All of these papers and references were scanned to determine whether or not they provided useful information to assist us develop production systems to improve meat quality and in particular that destined for Japan. Significant experimental data were collated and assembled below and results summarized.

None of the papers described scientific research that had resulted in large differences in marbling or intramuscular fat content of the l. dorsi (eye muscle).

Most of the work relating to feeding and pre feedlot entry suggested that body composition can be manipulated (and in particular the partitioning between muscle and fat) but that this had little or no effect on marbling at similar carcass weights or levels of finish. Feeding for lower rates of gain resulted in increased protein deposition per unit of liveweight gain and at slaughter resulted in higher lean meat yields at similar slaughter weights, or increased weights at similar levels of finish or body composition.

Marbling and intramuscular fat content appeared to be directly proportional to the number of days grain fed and therefore carcass weight. Composition of this fat became less saturated as grain feeding progressed. Intramuscular fat content increased by 0.021 % per day on feed which means an additional 100 days on feed would increase intramuscular fat content by 2.1% or two thirds of a marbling score.

Using a grower ration comprising predominately roughage improved marbling over using a grain based grower ration even though weight gains were the same during this phase, prior to a high energy finishing ration. In another experiment, lower energy finishing diets tended to reduce marbling and marbling was negatively related to retail product yield (therefore positively correlated to body fat content).

Cattle backgrounded on pasture before being grainfed had superior marbling, but they also had higher body weights. It appeared however that equal marbling could be achieved with fewer days on grain. Cattle slaughtered at 2 years of age had similar marbling after 140 days of grain feeding than cattle slaughtered at 15 months of age following 250 days of grain feeding, however, carcass weights were 317 and 207 kg for the 2 year old and 15 month old cattle respectively. At the same body weight, cattle put directly onto grain at a young age had better marbling.

There appeared to be only slight differences due to feed ingredients and marbling appeared to be more closely related to rate of gain during the feedlot phase than to feed ingredients. Corn (maize) as the main grain resulted in slightly better intramuscular fat as measured by marbling score, quality grade and chemical fat content. There were no significant effects on other quality attributes. Differences due to grain type were small and in another experiment, no difference was detected.

Reduced processing of grain may improve marbling slightly.

The use of protected lipid improved marbling score and quality grades marginally. Protected lipid use also changed the fatty acid composition of fat depots and it was reported that this change was complete within 50 days of feeding protected lipids. The addition of unprotected lipid had no effect.

Grainfeeding for 112 days increased intramuscular fat content of C18.1 fatty acid from 36.8% to 47.1% over grassfed and reduced the content of both C18 and C18.2. Other changes were minor. The authors also found that flavor was positively correlated with C18.1 and total unsaturated fatty acid content and negatively correlated to saturated fatty acid content amongst American consumers. Smaller changes in fatty acid composition accompanied shorter periods on grain. Fat hardness will also be influenced and there is evidence from industry observations that the grain used during grainfeeding has a considerable influence on fat quality.

The use of ionophores led to small (less than 10%) increases in marbling.

In vitro studies of fat cells from different sites suggested that subcutaneous fat cells were more active than intramuscular fat cells in taking up substrates. It also suggested that the cells changed with age of the cattle. Acetate was important with younger cattle as a precursor and it became less important with age. In subcutaneous fat, 70-80% of the acetyl units was derived from acetate. In intramuscular fat, 10-26% of the acetyl units was derived from acetate with the remainder being derived from lactate and glucose. The authors concluded that because of the difference in substrate use, there was the potential to manipulate partitioning between fat depots by altering the availability of substrates.

Higher energy feedlot rations increased daily gain,and feed conversion efficiency, however, protein deposition and retail product yield were reduced compared with lower energy density rations. At the same estimated body composition, cattle fed higher energy density rations had slightly higher marbling amounting to less than a third of a degree of marbling.

The use of hormonal implants or intact animals rather than castrates resulted in small reductions in marbling. Efficiency was increased by both treatments however. Implantation of heifers had similar effects to that in steers. Castration may have resulted in finer textured lean than intact and implanted steers.

Feedlot housing did not have a significant effect on marbling or meat quality in one experiment but a very minor effect in another.

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APPENDIX

Despite there being a lack of evidence from the scientific literature on the ability of us to manipulate marbling and other meat quality attributes through non genetic means, there is strong physical evidence that we can achieve significantly better quality than has been previously thought. The accepted wisdom, particularly in Japan has been that Australian genetics will never achieve better quality than Japanese dairy beef. This myth has now been destroyed. A small number of carcasses have been air freighted to Japan, graded by members of the Japanese Meat Grading Association in Japan and sold on the Japanese wholesale market for prices approaching Wagyu prices.

Attached are copies of the official Japanese grading sheets for a series of almost 40 carcasses air freighted to Japan from Australia in the past three months. These cattle were Angus cattle fed in Australia, slaughtered in Australia and graded on arrival in Japan. A selection of photographs is included showing the level of marbling achieved without the deposition of excessive amounts of subcutaneous and intermuscular fat. For comparison is a photograph of a carcass produced using common practice in Australia. These high grading carcasses have been fed for 400-500 days to achieve hot carcass weights of almost 450 kg. Highest marbling grade achieved was 9 with 4 and 5 being achieved regularly. These cattle are being fed according to traditional Japanese techniques used by the parent company in Japan.

JMGA graders appear to be somewhat harsher than Australian graders. A number of carcasses graded by AUSMEAT staff in Australia, all achieved marbling score 4 were sent to Japan in October and November and were consistently downgraded to marbling scores 2 and 3 by JMGA staff. To my untrained eye, AUSMEAT graders were correct according to the marbling chips and JMGA graders were rather hard.

The Japanese meat grading system is not a complete description of carcass and meat quality. Wagyu carcasses achieve much higher prices than Holstein carcasses of the same grade. The following table lists quotations for Wagyu, Holstein and crossbred steers on the Tokyo wholesale market for early November. Holstein steers achieve a discount of some 40% compared with Wagyu of the same grade (comparing B2 and B3 prices of each) and crossbred or F1 carcasses achieve prices closer to Wagyu than to Holsteins.

QUALITY GRADE	5	4	3	2	1	Number
Wagyu steer A	2685	2111	1615	1294	-	140
Wagyu steer B	2607	2039	1566	1316	673	21
Holstein steer B	-	1155	1096	1062	340	16
Holstein steer C	-	1238	1060	940	-	5
Cross bred steers B	2014	1847	1481	1250	-	25
Cross bred steers C		1517	1396	1214	-	7

Source: Shoku Niku Sokuho 4-11-92

I visited the Japanese Meat Grading Association in particular to ascertain what difference there was in meat quality between domestic Wagyu and domestic Holstein beef that was not described by the JMGA grading system but that caused the pricing difference for the same quality grade. A number of explanations arose as follows.

1. All the quality assessments that make up a grade are not equally valued by meat buyers (marbling is more closely correlated to price than any other quality attribute).
2. Wagyu carcasses are normally downgraded for marbling whereas Botoku carcasses are normally downgraded for poor meat texture and tightness.
3. Meat drip, which is related to water content and muscle texture and tightness is a

function of cattle age. Wagyu are generally slaughtered at 30 months of age whereas Dairy steers are generally slaughtered at 23 months of age.

It would appear that the price difference between Wagyu and Holstein beef of the same grade can be explained by differences in the quality factors above. This however does not explain the price difference between imported and domestic beef of similar quality. Spot market investigations would suggest imported beef receives less than 50% of the price of domestic beef of the same quality at present. Feeder steers of Australian origin, fed in Japan to achieve B2-B3 quality are currently selling for 2300 yen per kg for boneless boxed beef (comprising 58-60% of carcass) compared with imported beef of the same quality, but only the higher value cuts (43% of carcass weight in a 12 cut full set) achieving 1300 yen per kg. Research needs to be undertaken to understand the reasons for this price difference and possible means of closing the gap.

Plate 1. Carcass produced using "standard practice" in Australia destined for Japan.

Plate 2. B5 carcass produced from Australian Angus in Australia using Japanese technology. This view shows the carcass at the quartering site and reveals extensive marbling fat in the L.dorsi with relatively little subcutaneous and intermuscular fat.

Plate 3. Carcass shown in plate 2 showing the extensive marbling in the topside.

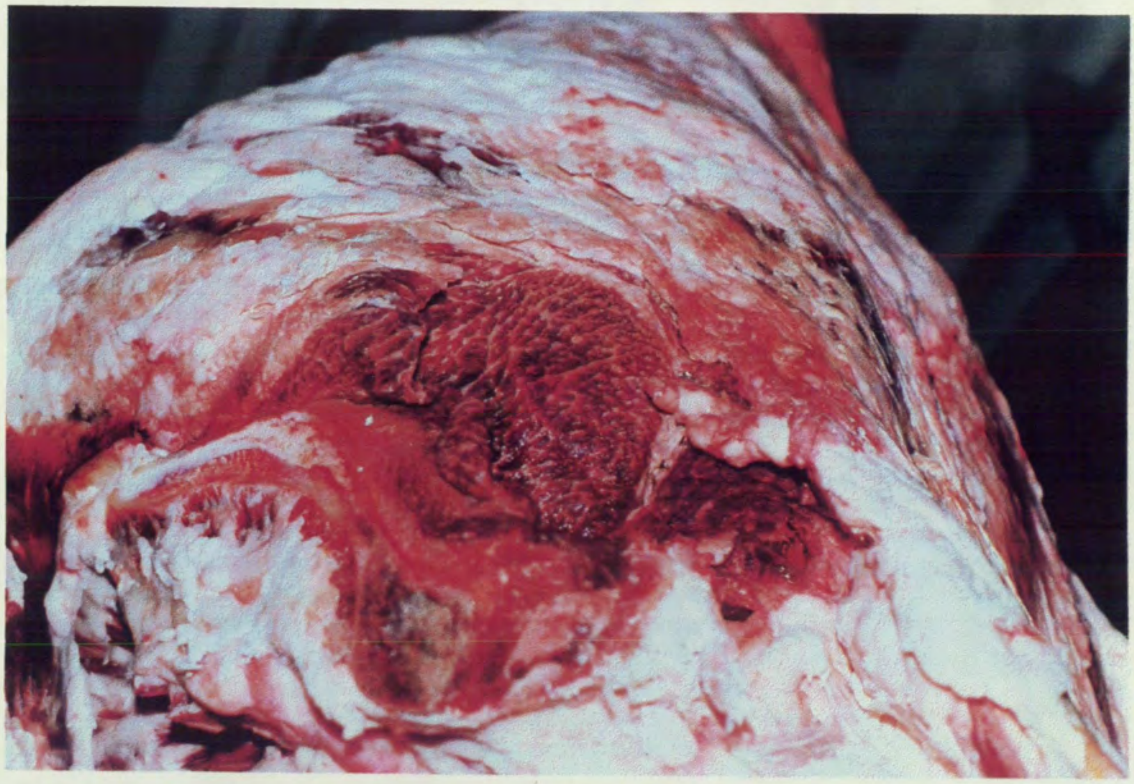

Plate 4. B2 carcass produced as above.This view shows the extensive marbling compared with our concepts of B2 grade.

Plate 5. B2 carcass above.This view shows the full length of the rib giving an indication of the relatively small amounts of excess fat on the carcass.

Insert 1. Japanese Meat grading sheet for Australian carcasses sold November 11th, 1992.

牛枝肉格付明細書

平成 4 年 11 月 11 日

社団法人 日本食肉格付協会　名古屋 事業所

番号	出荷者名	等級 歩留	等級 肉質	歩留 枝肉重量(左・右)	歩留 胸最長筋面積	歩留 ばらの厚さ	歩留 皮下脂肪の厚さ	歩留 歩留基準値	肉質 BMS No.	肉質 脂肪交雑等級	肉質 BCS No.	肉質 光沢	肉質 等級	肉質 締まり	肉質 きめ	肉質 等級	肉質 BFS No.	肉質 光沢と質	肉質 等級	瑕疵	その他	品種性別	未経産・経産	取引単価
1	オーストラリア 482.0	B	2	239:7	41	8.5	3.0	69.7	3	3	5	2	2	2	3	2	3	4	4			外ヌ		
			–	:		.	.	.																
3	426.2	B	3	212:5	47	8.5	3.5	70.8	5	4	4	4	4	3	4	3	3	4	4			外ヌ		
4	409.4	B	3	204:0	46	8.0	3.4	70.5	5	4	5	3	3	3	4	3	3	4	4			〃		
5	447.4	B	3	221:5	45	8.6	3.0	70.9	4	3	4	3	3	3	3	3	3	4	4			〃		
6	391.0	B	2	192:7	41	9.0	3.2	70.5	3	3	4	2	2	2	2	2	2	4	4			〃		
7	477.7	B	5	237:2	43	10.5	2.5	71.8	8	5	4	5	5	5	5	5	3	5	5			〃		
8	397.6	B	4	197:4	42	8.6	2.6	71.3	7	4	4	4	4	4	5	4	3	4	4			〃		
9	396.4	B	5	196:7	45	8.2	4.5	69.7	9	5	4	5	5	5	5	5	3	5	5			〃		
10	442.9	B	2	219:3	40	10.8	3.9	70.8	3	3	5	2	2	2	2	2	3	4	4			〃		
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			–	:		.	.	.																
			–	:		.	.	.																
			–	:		.	.	.																
			–	:		.	.	.																

（様式A－1）

注）
1. 歩留等級はA，B，C，肉質等級は5，4，3，2，1とする。
2. 歩留等級の補正は，その他の欄に①，②で記入する。
3. BMS No.欄には，右表のNo.を記入する。
4. 肉質の各項目の等級の判定は判定基準により記入する。
5. 瑕疵の略記号は，シミ→ア，ズル→イ，シコリ→ウ，アタリ→エ，カツジョ→オ，その他→カとする。

BMS No.	1	2	3	4	5	6	7	8	9	10	11	12
脂肪交雑基準	0	0+	1−	1	1+	2−	2	2+	3−	3	4	5

Insert 2. Japanese Meat grading sheet for Australian carcasses sold October 14th, 1992.

格付明細書

平成 4 年 10 月 14 日　相対販売　社団法人 日本食肉格付協会　名古屋事業所

番号	出荷者名 オーストラリアカーカス	等級 歩留	等級 肉質	歩留 枝肉重量（左・右）	歩留 胸最長筋面積	歩留 ばらの厚さ	歩留 皮下脂肪の厚さ	歩留 歩留基準値	肉質 BMS No.	肉質 脂肪交雑等級	肉質 BCS No.	肉質 光沢	肉質 等級	肉質 締まり	肉質 きめ	肉質 等級	肉質 BFS No.	肉質 光沢と質	肉質 等級	瑕疵	その他	品種性別	未経産・経産	取引単価
1	331.8	B	2	166.9	35	7.5	2.8	70.2	3	3	5	3	3	2	2	2	3	4	4			メス		
2	407.2	C	3	201.7	27	8.0	3.3	68.2	4	3	3	4	4	4	4	4	3	4	4			〃		
3	389.8	B	4	184.0	39	8.5	2.8	70.8	7	4	4	4	4	4	4	4	3	4	4			〃		
4	342.4	B	3	174.5	35	8.2	2.2	71.0	4	3	4	3	3	3	3	3	3	4	4			〃		
5	444.9	B	3	223.9	42	8.5	4.2	69.7	4	3	5	3	3	3	3	3	3	4	4			〃		
6	420.0	C	2	212.8	32	8.0	6.0	66.2	3	3	5	2	2	2	2	2	3	4	4			〃		
7	426.4	C	3	214.4	39	8.6	4.9	68.4	5	4	4	3	3	4	3	3	3	4	4			〃		
8	444.3	C	2	226.0	41	7.8	3.8	68.8	3	3	5	3	3	2	3	2	3	4	4			〃		
9	493.5	B	3	240.2	49	9.4	3.1	71.0	4	3	4	3	3	3	3	3	3	4	4			〃		
		–		:		.	.	.																
		–		:		.	.	.																
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		–		:		.	.	.																
		–		:		.	.	.																
		–		:		.	.	.																

SOLD PRIVATELY, NO QUOTE

（様式A－1）

注）
1. 歩留等級はA，B，C，肉質等級は5，4，3，2，1とする。
2. 歩留等級の補正は，その他の欄に①②で記入する。
3. BMS No.欄には，右表のNo.を記入。
4. 肉質の各項目の等級の判定は判定基準により記入する。
5. 瑕疵の略記号は，シミ→ア，ズル→イ，シコリ→ウ，アタリ→エ，カツジョ→オ，その他→カとする。

BMS No.	1	2	[illegible]	4	5	6	7	8	9	10	11	12
脂肪交雑基準	0	0+	[illegible]	1	1+	2−	2	2+	3−	3	4	5

牛枝肉格付明細書

平成 4 年 10 月 14 日　　發食 10/15上場 社団法人 日本食肉格付協会　　名古屋 事業所

番号	出荷者名 オーストチルドクーロス	等級 歩留	等級 肉質	歩留 枝肉重量 (左・右)	胸最長筋面積	ばらの厚さ	皮下脂肪の厚さ	歩留基準値	肉質 BMS No.	脂肪交雑等級	BCS No.	光沢	等級 (Grade)	締まり	きめ	等級 (Grade)	BFS No.	光沢と質	等級 (Grade)	瑕疵	その他 PRICE	品種性別	未経産・経産	取引単価
1	375.7	B	2	184.8	39	7.7	2.8	70.4	3	3	4	3	3	2	3	2	3	4	4		1207	ヌキ		
2	399.1	B	4	196.7	47	8.3	2.9	71.5	7	4	4	4	4	4	4	4	3	4	4		1835	〃		
3	375.3	B	2	184.8	41	8.6	2.1	71.9	3	3	5	2	2	2	2	2	3	4	4		1146	〃		
4	384.4	B	2	194.8	40	8.1	3.5	70.0	4	3	4	3	3	2	3	2	3	4	4		1209	〃		
5	461.1	B	2	230.0	42	9.2	4.5	69.2	3	3	5	2	2	2	2	2	3	4	4		1157	〃		
6	405.9	B	4	202.4	52	8.2	4.0	71.0	6	4	4	4	4	4	4	4	3	4	4		2063	〃		
7	448.2	C	3	226.1	37	7.7	4.0	68.1	4	3	4	3	3	3	3	3	3	4	4	ウ	ソウボウ筋	?		
8	399.1	B	3	200.0	43	8.2	3.0	70.7	4	3	5	3	3	3	3	3	3	4	4		1350	〃		
9	422.2	B	3	207.0	38	8.0	3.8	69.1	5	4	5	3	3	3	3	3	3	4	4		1350	〃		
10	331.7	B	5	164.5	39	7.5	2.4	71.2	8	5	4	5	5	5	5	5	3	5	5		2006	〃		
																					Y/kg			

(様式A－1)

注) 1. 歩留等級はA，B，C，肉質等級は5，4，3，2，1とする。
2. 歩留等級の補正は，その他の欄に①，②で記入する。
3. BMS No.欄には，右表のNo.を記入する。
4. 肉質の各項目の等級の判定は判定基準により記入する。
5. 瑕疵の略記号は，シミ→ア，ズル→イ，シコリ→ウ，アタリ→エ，カツジョ→オ，その他→カとする。

BMS No.	1	2	3	4	5	6	7	8	9	10	11	12
脂肪交雑基準	0	0+		1	1+	2−	2	2+	3−	3	4	5

Insert 3. Japanese Meat grading sheet for Australian carcasses sold October 14th, 1992.

MARBLING IN BEEF

Key to inserts (Japanese grading sheets).

COLUMN	ITEM
1	Carcass number
2	Carcass weight (kg)
3	Official grade (Yeild and quality)
4	Side weight (kg)
5	Eye muscle area (sq cm)
6	Rib thickness (cm)
7	Subcutaneous fat thickness over eye muscle (cm)
8	Carcass meat yield estimate as estimated from the above parameters
9	Beef marbling score number (BMS)
10	Grade category (1-5) according to marbling
11	Beef color score (BCS)
12	Meat luster
13	Grade category (1-5) according to meat color & luster
14	Meat tightness
15	Meat texture
16	Grade category (1-5) according to meat texture and tightness
17	Fat color score (BFS)
18	Fat luster
19	Grade category (1-5) according to fat quality
20	-
21	Spot price at auction if available (y/kg)

Below is a summary of the shipments taken from the attached grading sheets showing the distribution of quality and yield grades. Although most fall into the B2 and B3 category, there are an equal number above this and noticeably, none below quality grade 2.

CARCASS GRADING SUMMARY

	YIELD GRADE			
QUALITY GRADE	A	B	C	TOTAL
5		3		3
4		4		4
3		8	3	11
2		8	2	10
1				0
TOTAL	0	23	5	28