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FACTORS AFFECTING ESTIMATION OF MARBLING IN CATTLE AND THE RELATIONSHIP BETWEEN MARBLING SCORES AND INTRAMUSCULAR FAT

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SUMMARY

The aim of this study was to investigate the relationships between various estimates of marbling in Jersey and Limousin crossbred steers with intramuscular fat percentage (IMF%) as determined by solvent extraction. The correlations between IMF% and various marbling scores ranged from 0.67 to 0.79. AUS-MEAT, MSA or USDA scoring systems were correlated, and ranked animals similarly. However, the best correlation with IMF% was found to be with the AUS-MEAT marbling score. When the range of IMF% was assigned to different scores within each system, the AUS-MEAT and USDA systems were similar whereas MSA scores had a higher concentration of fat per score and a broader range of concentrations. The only factors influencing assessment of marbling were IMF% and breed. Other traits, such as loin temperature, eye muscle area, melting point, fat colour and meat colour were not significant. Jersey cross steers had higher marbling scores (1.9 vs 0.8) and IMF% (6.4 vs 4.4%) than Limousin cross. A breed by sire interaction in marbling was also detected.

Keywords: marbling, intramuscular fat percentage, cattle

INTRODUCTION

Marbling of meat is defined as the appearance of evenly distributed white flecks or streaks of fatty tissue between the muscle fibers and is measured subjectively. It is not a true measure of intramuscular fat (IMF), which quantifies the total amount of fat present in muscle (both vesicle triacylglycerol and membrane phospholipid) and does not take into account the fineness nor the distribution of the fat globules throughout the muscle. In Australia, there are three commonly used subjective assessment systems of marbling: (i) the 7-point scale (0-6) AUS-MEAT system performed on chilled carcasses and scored against reference standards, (ii) the Meat Standards Australia (MSA) assessment using the same reference standards as AUS-MEAT (0-6) but with a finer scale of 0.1 increments, and (iii) the United States Department of Agriculture (USDA) system where scores range from 100 to 1000 in increments of 10. High but variable correlations have been reported between subjective measurements of marbling and IMF% when different systems, cattle breeds, carcass quartering sides or various ranges of marbling scores have been examined (Savell *et al.*1986; Taylor and Johnson 1992). The aim of this study was to examine some of those parameters in more detail by (i) investigating the influence of breed and sire on marbling, (ii) assessing the relationship between marbling score and IMF%, (iii) comparing the relationships between different scoring systems and IMF% within each system, and (iv) investigating the factors influencing marbling assessment.

MATERIALS AND METHODS

Animals and management

The animals used in this study were part of the Davies Cattle Gene Mapping Herd, ¾ Jersey (XJ) and ¾ Limousin (XL) (Kruk *et al.* 1999). They were born between April-May, 1997. The animals comprised 50 XJ and 31 XL steers, progeny of pure Jersey and Limousin cows crossed to the three F1 (Jersey/Limousin) bulls (Animal Nos. 361, 368, 398). The steers were raised on pastures under the same management conditions, weaned at 250 days of age and fed a grain based ration for 170 days.

Slaughter, measurements and sample collection

All steers were slaughtered in the morning after stunning by use of a captive bolt. Following line processing, the carcasses were stored in the (0-4°C) chiller. On the next day, approximately 18 hours after the slaughter, carcass assessment was performed by an accredited AUS-MEAT or MSA grader. Parameters such as meat colour (MC), fat colour (FC), eye muscle area (EMA), loin temperature (LT), ossification, pH, AUS-MEAT marbling (MbAM), MSA marbling (MbMSA) and USDA marbling (MbUSA) were assessed. The left side of each carcass was boned out and eye round (*M. semitendinosus*) and strip loin (*M. longissimus dorsi*) samples were collected. A 1.5 cm thick steak was cut from the anterior part of the strip loin, placed in a sealable plastic bag and frozen at -20°C until further analysis.

Chemical analyses

The methods used for lipid extraction, fatty acid analysis and melting point determination are those described by Malau-Aduli *et al.* (2000). All visible seam fat was removed from strip loin cuts and approximately 100 g was homogenised in a small food processor. An accurately weighed sub-sample (approximately 2g) was then taken and the lipid was extracted with chloroform:methanol (2:1) following the method of Christie (1989). This procedure extracts both triacylglycerols and phospholipids. Individual fatty acids were separated and identified by gas-liquid chromatography and the major saturated (SFA) and mono unsaturated (MUFA) groups calculated by summation of individual saturated or *cis* mono-unsaturated acids (cMUFA). Melting point (MPt) was recorded as the 'slip point' of samples of fat taken from adipose tissue adjacent to where muscle was sampled (AOCS, 1993).

Statistical analysis

Least squares analysis of variance was carried out using Proc GLM (SAS 1989). Two models were applied. Model 1 investigated the influence of breed of dam and sire on intramuscular fat content and included breed, sire and breed by sire interaction. Model 2 investigated the influence of various carcass traits (EMA, LT, FC, MC, IMF%) on marbling assessment and included these parameters and their interactions. The interactions were not significant ($P>0.05$) and were removed from the model leaving only the main effects. Correlations between variables were estimated using Proc CORR (SAS 1989).

RESULTS

Breed of dam had a significant effect on marbling score regardless of the assessment method (Table 1). Jersey steers had significantly higher marbling scores ($P<0.05$) than the Limousin steers by each of the three scoring systems (Table 1A). Correspondingly, IMF% was significantly higher in Jersey cattle as was mono-unsaturated fatty acids (cMUFA). Saturated fatty acids (SFA) and melting point (MPt), were lower.

The full range of marbling scores was not represented for each grade scheme (Table 1B). MbAM varied from 0 to 4 with the last score represented only by one animal. MbMSA varied from 0 to 2, and the MbUSA varied between 200 and 600. The increase of marbling scores was accompanied by an increase in IMF%. The MbAM and MbUSA scores were similar in IMF%, whereas MbMSA had higher percentage of intramuscular fat and a broader range of concentrations for each score (Table 1B).

Table 1. 1A. Breed differences in marbling, fat composition and intramuscular fat percentage (IMF%). 1B. Association of marbling scores with IMF%

	1A		1B								
Parameter	XJ	XL	#	MbAM	IMF%	#	MbMSA	IMF%	#	MbUSA	IMF%
MbAM	1.9±0.09^{A}	0.8±0.12^{B}	7	0	3.4±0.82	17	0	4.4±1.16	2	200	3.0±0.95
MbMSA	1.4±0.05^{A}	1.1±0.07^{B}	35	1	4.7±0.93	60	1	5.7±1.46	16	300	4.6±0.96
MbUSA	373±8.3^{A}	313±11.2^{B}	31	2	6.5±1.14	4	2	8.0±1.75	44	400	5.6±1.39
Mpt	36.8±0.44^{B}	38.9±0.59^{A}	7	3	7.9±1.32	-	-	-	17	500	7.5±1.20
SFA	46.1±0.57^{B}	48.9±0.76^{A}	1	4	10.1	-	-	-	2	600	10.1
cMUFA	49.6±0.55^{A}	47.0±0.73^{B}	-	-	-	-	-	-	-	-	-
IMF%	6.4±0.20^{A}	4.4±0.26^{B}	-	-	-	-	-	-	-	-	-

Note: all abbreviations as defined in the materials and methods, # = number of animals, $^{A-B}$ within rows means of the same class followed by the same letter are not significantly different ($P>0.05$).

The influence of various carcass characteristics such as size of the eye muscle area, meat colour, fat colour, melting point of fat and loin temperature did not have a significant effect on marbling assessment (Model 2). The only significant effects were observed with breed and intramuscular fat percentage.

Unlike breed, sire influence was not generally significant except observed breed by sire interaction for different sires within the Jersey breed. Significant differences were noted regardless of the estimation of marbling score by AUS-MEAT, MSA or USDA grading. Significant Jersey breed differences were found for sire 361 versus sires 368 and 398 in every estimate of marbling except the MbUSA where the sire 361 was only significantly different from the sire 369 (P<0.05) but not from 398 (P<0.07).

The correlations between marbling scores and IMF% were high and significant (Table 2). The highest correlation was observed with MbAM and the lowest with MbMSA. Marbling was also associated with fatty acid composition. MbAM and MbUSA were negatively correlated with SFA and the MbAM was positively correlated with cMUFA. The correlations were moderate. A large and highly significant negative relationship was found between SFA and cMUFA. The other traits such as FC and MC were moderately associated with MbAM. A similar association with MC was found for MbMSA. The saturation of fat was moderately correlated with fat colour (FC), which in turn was positively correlated with meat colour (MC).

Table 2. Raw correlations between marbling and various carcass parameters

	MbAM	MbMSA	MbUSA	SFA	cMUFA	IMF%	FC	MC
MbAM		0.76***	0.81***	-0.27**	0.25*	0.79***	0.25*	0.23*
MbMSA			0.84***	ns	ns	0.67***	ns	0.23*
MbUSA				-0.24*	ns	0.71***	ns	ns
SFA					-0.98***	ns	-0.40***	ns
cMUFA						ns	0.41***	ns
IMF%							ns	0.34**
FC								0.27**
MC								

Note: ***P<0.001, **P<0.01, *P<0.05, abbreviations as described in materials and methods

DISCUSSION

Marbling, by definition, represents the distribution of white flecks or streaks of fatty tissue between the muscle fibers. Such three-dimensional structures may be associated with large errors when expressed as a two-dimensional subjective score and represented as IMF% (three-dimensional with solvent extract containing also membrane phospholipids). In our study, marbling score varied from 0-4, 0-2.5, 170-550 in AUS-MEAT, MSA, USDA scales, respectively. The concentration of intramuscular fat ranged between 2.0-10.1%.

As expected, the various estimates of marbling were highly correlated, demonstrating that all grading systems rank animals in a similar order. The highest correlation between MbMSA and MbUSA can probably be explained by the similarity in the scale used for the estimate. The MSA assessment using the AUS-MEAT scale (expressed in finer intervals) is probably closer to that of the MbUSA scale than the AUS-MEAT assessment itself. However, as the MbMSA and MbUSA scoring was performed by the same assessor and the MbAM was performed by another assessor, differences between assessors cannot be ruled out and require further investigation.

The MSA marbling was poorly associated with IMF% compared to the other scoring systems. The highest correlation with IMF% was with MbAM, suggesting that IMF% can be better predicted by marbling when using an integer scoring scale. The correlations with IMF% ranged from 0.67-0.79 in this study and are similar to 0.71 reported by Ferguson (2001). However, in other Australian studies, the correlations with AUS-MEAT score were lower, ranging from 0.32 to 0.57 (Taylor and Johnson 1992).

Significantly higher correlations between IMF% and marbling scores were reported in US and Japanese studies (marbling was measured in the USA and Japanese scales). The correlations ranged from 0.87 to 0.89 (Sarvell *et al.* 1986; Cameron *et al.* 1994; Okabe *et al.* 1999). The differences between the various reports can be accounted by many factors such as the range of marbling scores, the range of IMF content, the method of intramuscular fat extraction, the grading system and the quartering site.

The scores in the MbMSA system had higher concentrations of IMF%. The MbMSA also had a broader range of IMF% within each score compared to the two other scoring systems. The corresponding IMF% values for each AUS-MEAT score in other reports (Bindon 2001) were lower than our results. However, the increase of IMF% per score was very similar in our data. Moreover, a similar increase of IMF% was found in our study regardless of the scoring method. The slight discrepancy between our reports and the others in terms of IMF% per score can be accounted for the differences of IMF extraction. The method used here was based on that of Christie (1989) using a polar solvent mixture rather than neutral di-ethyl ether. When meat is low in fat, significantly more total lipid is extracted with this solvent mixture due to the phospholipid content of tissue membranes (Siebert *et al.* 1996).

The low and positive correlations between some marbling scores and meat and fat colour suggests that these parameters might influence the estimation of marbling. For instance, a positive correlation with meat colour would provide a better contrast of marbling in a darker background. Also more yellow fat might reflect light differently to white fat. These factors are unlikely to affect marbling scores, however, since there are also positive correlations between IMF% and meat and fat colour so the correlation with marbling is likely to be real.

In the study herein, Jersey steers had higher marbling scores than the Limousin steers. Breed effect on marbling has been reported previously. In other studies by our group, (viz. the Southern Cross breeding experiment which consisted of seven different sire breeds), marbling was also affected by breed (Malau-Aduli *et al.* 2000). The significant breed difference for MbMSA and MbUSA marbling scores was no longer significant when IMF% was fitted as a covariate. However, it is interesting to note that the difference between breeds was still significant for MbAM. This suggests that there may be a relationship between marbling scores and fat distribution, which is not precisely evaluated when using a coarser scale (AUS-MEAT). The distribution was not measured and may be the cause of the difference. Additional covariates fitted in the model led to the conclusion that the breed differences were not due to differences in fatty acid composition (melting point) or degree of muscling (eye muscle area). On the other hand, the quality of the evaluation cannot be neglected as AUS-MEAT scores were assessed by a different assessor. The influence of the assessor on the quality of testing will be a subject for further study.

There was a large sire influence evident only in the Jersey breed, where breed by sire interaction was statistically significant. The Jersey progeny from sire 361 had lowest marbling scores while the Limousin progeny did not differ from the progeny of the other sires. The genetic influence on marbling has been reported by others (Burrow, 2001) and our study confirms that selection for marbling may improve this trait. However, different scoring methods have to be considered whether selecting for IMF% or marbling.

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