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Meat Technology Update

Newsletter 3/05

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Marbling and quality of beef

Marbling is a key market specification for many of the two million cattle turned off from Australian feedlots each year. The information in this update is based on papers published in 2004 when the entire July edition of the Australian Journal of Experimental Agriculture was devoted to the role of marbling in the eating quality of beef.

When it comes to defining and assessing meat quality, there is ongoing debate about whether the link between marbling and eating quality is good enough to warrant the costs of achieving extensive marbling. There is no doubt that it is a major determinant of carcase value for Australia's most valuable export beef market, Japan. The link between marbling and eating quality for other markets has been more difficult to establish scientifically.

USA beef-grading schemes have included marbling as an assessable component for nearly 50 years and premiums have been paid on the basis of marbling. Consumers in the USA have accepted that marbling has a significant influence on beef quality. Likewise the growth of premium markets for marbled beef in Japan over the last 10 or more years, confirm the recognition of marbling there.

Extensive grain feeding of cattle in the USA results in meat that is generally more marbled and contains more fat than domestic Australian market beef. In Australia, however, marbling is of unquestionable significance, particularly in the export-beef sector—given that, in the last few years, 25% of all slaughter cattle (including nearly 50% of steers), have been 'finished' in feedlots. It has not yet achieved prominence in the domestic market where almost all beef available is grass fed, although often finished in feedlots for up to 70 days.

This update investigates some of the factors that affect the development and assessment of marbling as a meat-quality attribute.

Marbled beef (photo courtesy of AUS-MEAT Ltd)

Role of marbling in dietary fats and human health and nutrition

Fats are the most concentrated form of energy in meat at 38 kilojoules (or 9 calories) per gram. The health and nutrition issues relating to fats are affected by the types of fatty acid contained in the fats. Saturated fatty acids, such as palmitic and stearic acids, contain no double bonds as the bonds are fully saturated with hydrogen. Monounsaturated fatty acids, which in beef fat are comprised mainly of oleic acid, have only one double or unsaturated bond. Polyunsaturated fatty acids, such as linoleic acid, are present only in small amounts in beef fats. They contain 2 or more unsaturated bonds.

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The main concerns about dietary fats for human health are:

- obesity (and related high blood pressure and Type 2 diabetes) due to total fat intake and associated potential excess energy content; and
- heart disease, which is related in part to total fat intake and its link to obesity, but also to the individual types of fat consumed. It is recognised that the most significant risk occurs with saturated fats.

Australian Bureau of Statistics data from 1997 show that, at that time, red meat contributed only 9% and 7% of dietary fat to males and females respectively. Contrary to common belief, red meat contributes more unsaturated fat than saturated fat on an edible portion basis, and about 40% of the saturated fat in beef is stearic acid—a fatty acid that appears not to create a heart health risk because it is not linked to elevations in plasma cholesterol or low density lipoproteins (LDL).

The bulk of the fat in meat is present in the form of:

- subcutaneous (selvedge) fat;
- intermuscular (seam) fat; or
- intramuscular fat or marbling fat (between muscle fibres or cells)

There is another functionally important category of fat that is located within the individual cells or muscle fibres and this contributes about 1% to the fat content of meat. This fraction is made up largely of structural phospholipids and vesicular triglycerides.

It has been suggested that marbling fat is compositionally different from other meat fats and may therefore be more 'healthy'. This idea largely resulted from studies reporting fatty acid compositions of total fat from relatively lean meat, where the polyunsaturated phospholipids predominate; however, any differences in the composition of dissected marbling fat and selvedge or seam fat are insignificant compared to the issue of total fat content. All fats provide a concentrated energy source. Therefore, the greater the marbling, the higher the energy content.

It may be possible to improve the 'healthiness' of the fatty acid profile of beef by manipulating fatty acid composition through selective breeding, by genetic engineering and/or by altering feeding regimes. In heavily marbled beef, the intramuscular fat content may be 15% or higher (see below). There may be health advantages to consumers of such beef if the level of saturation could be reduced; however, if a change in the fatty acid profile is accompanied by an increase in marbling, any benefit will be offset by the increase in energy density.

Measurement of marbling

The measurement of marbling is mostly by subjective visual assessment of the distribution and degree of fat deposition between muscle fibres. Measurement may be subject to operator error and is influenced by meat temperature.

In the living animal, fat is in a semi-fluid state. On chilling, the triglycerides solidify and become opaque and visible. The temperature at which this occurs depends largely on the melting points of the individual fatty acids. Marbling fat comprises a range of fatty acids and each has an individual melting point (e.g. palmitoleic melts at 0°C while stearic melts at 70°C). The visual appearance of marbling at chiller temperatures when assessment occurs will therefore depend on the melting points of the constituent fatty acids. Animal nutrition and climate (both season and location) affect fatty acid composition and the resulting fat hardness and marbling appearance, though not always in a predictable way.

Chemical extraction gives an objective measure (chemically extracted intramuscular fat, IMF%) of all fat in the muscle, both marbling fat and that within fibres and cells. The relationship between marbling fat and IMF% is a good one because the amount of fat within the fibres and cells is relatively constant at about 1%. Often, however, the relationship between visual marbling score and IMF% is not good because of the subjective nature of the marbling score. The score is only a moderate predictor of IMF%, and a poor predictor of flavour and other eating-quality attributes.

As visual assessments are compromised by their subjective nature and the variation in fatty acid composition, several objective measurement technologies have been developed and evaluated for on-line measurement of marbling. These include video image analysis, near infrared spectroscopy, ultrasound, light reflectance and bioelectrical impedance. Of these, video image analysis and the Danish bioelectrical impedance device offer the most promise in terms of measurement accuracy and suitability for on-line use in abattoirs.

Marbling and meat grading

The United States Department of Agriculture (USDA) and the Japanese Meat Grading Association (JMGA) have had standardised meat-grading systems for many years. These systems work well where there are uniform production methods that do not give the variations in carcass weight, breed, age, fatness and finishing regime found in Australia.

While these systems provide useful trading information and reasonably accurate eating-quality signals to consumers in their respective countries, they do not perform well under Australia's variable conditions. The Meat Standards Australia (MSA) system has been developed to provide consistent and reliable eating-quality information to consumers by considering meat and processing factors in addition to those in the US and Japanese systems. All three systems include marbling as a factor in quality grading where assessment is based on a comparison to a visual standard.

Marbling and eating quality

A major study by the CRC for Cattle and Beef Quality has shown that as IMF% increases, Australian consumers assign higher scores for tenderness, juiciness, flavour, and overall liking, but the relationships plateau between 14 and 17 IMF%. The study also showed that if young cattle are processed in a manner that controls toughness (through use of tenderstretch, electrical stimulation and/or ageing), the flavour and juiciness scores for grilled steaks served to Australian consumers plateau at a higher IMF%. One of the often quoted attributes of feedlot-finished beef is the more desirable flavour and juiciness scores. The study showed that the effect was largely attributable to the animal age at slaughter. For instance, northern pasture-finished cattle were less juicy and flavoursome, simply because they were older at the target slaughter weight. When feedlot and pasture treatments in the study were compared at the same degree of toughness, IMF% and animal age, there was little difference in flavour scores.

Manipulation of marbling through breeding and feeding regimes

Marbling is thought to occur in 3 distinct phases: (i) a period of growth up to about 200 kg hot carcase weight where intramuscular fat does not increase; (ii) a period of linear development as carcase weight increases from 200 kg to around 450 kg; and (iii) attainment of mature body size (around 500 kg depending on genotype) at which intramuscular fat content appears to reach a maximum.

The actual weight ranges in which these phases occur depend on the mature body size of the animal. This is shown graphically in Figure 1. Line A reflects the pattern of change in IMF% for animals that mature earlier than those reflected by B.

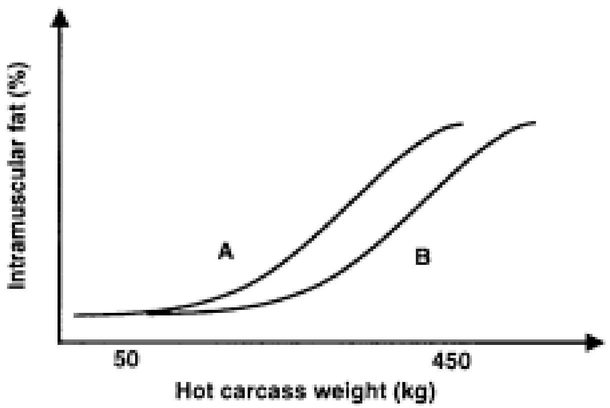

Figure 1. Development of intramuscular fat in cattle of different mature live weights (B>A) (Pethick *et al.*, 2004)

The initial or pre-feeding level of intramuscular fat in cattle at induction into feedlots has an important influence on the final level (Figure 2). In order to achieve a final intramuscular fat content of 15% at 400 kg HCW and generate an AUS-MEAT marbling score of 4, the intramuscular fat content needs to be about 5% at the typical live weight for Australian cattle entering feedlots.

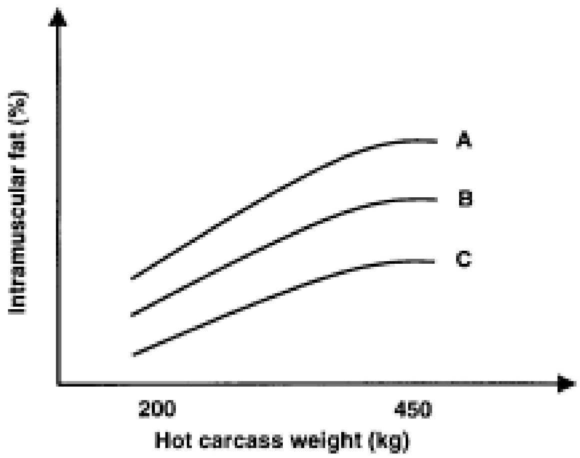

Figure 2. Intramuscular fat levels in beef cattle showing the effect of the initial intramuscular fat content (A>B>C) on the final value in cattle of similar growth potential on similar diets. (Pethick *et al., 2004*)

Factors widely believed to affect the initial level of intramuscular fat include:

- weight at entry to feedlot relative to mature weight;
- genetic propensity to marble;
- mature body size or maturity type;
- pre-feedlot growth rate and pattern of growth.

There has been a widespread belief that the greatest potential for the manipulation of intramuscular fat during fattening is via an increase in the net energy of the ration by, for instance, increasing the processed cereal grain content of the diet, or by increasing the lipid content of the diet; however, nutritional manipulation of marbling remains difficult. The following facts are known. High-energy grain diets achieve higher marbling than pasture diets. Within grain-based feedlot diets, higher marbling is achieved with maize than barley; while barley diets are, in turn, better than sorghum. Steam flaking produces higher marbling than dry rolled grain, and this effect is more marked with sorghum than maize.

Beyond these key points there are many uncertainties. The effects of diets with: high protein; low protein; protected protein; protected lipid; added oil; with and without calcium; and induced vitamin A deficiency, have all been investigated. None of these manipulations have given consistent improvement in marble score or IMF%. Commercial feedlots supplying premium Japanese markets may have dietary formulations that enhance marbling, but, because of its proprietary nature, the information is not available and has not been independently verified.

Results from breeding projects have provided improved understanding of breed and genetic effects on IMF% and marble score. Marbling is moderately to highly heritable in both temperate and tropical breeds. Estimated breeding values (EBVs) for IMF% have been released to industry for several hundred sires across 7 breeds. Heritability estimates confirm that genetic progress will be faster when selection is based on IMF% rather than marble score. Genetic correlations of IMF%

with growth, retail yield, P8 fat, residual feed intake and tenderness are now available to underpin selection indices.

At least one suitable direct gene marker has been identified for the marbling trait and is now being marketed as GeneSTAR marbling. Other favourable chromosomal regions are under investigation.

Opportunities for marbling as a quality attribute

While it is unlikely that all factors contributing to variation in marbling will be accounted for, it is likely that research will generate sufficient knowledge for the cattle industry to better manage marbling in a production situation.

Recently there has been spectacular progress in understanding the genetic factors that control marbling, to the point that gene markers can be used to promote particular animal lines to produce meat specifically for the Japanese market.

The Japanese predilection for highly marbled beef appears to be derived from their specific cooking traditions. This type of consumer preference has no equivalent in 'western' beef markets; however, comprehensive palatability tests in the MSA scheme for eating-quality assessment have shown that marbling does have an influence on juiciness and flavour. This is particularly relevant in MSA 4-star and 5-star grades. As a result the Australian industry is reassessing the effect of marbling on eating quality.

While marbling is now becoming acknowledged as an important future issue for the Australian domestic market, more work is required, specifically in the area of measurement systems relevant to this market, to take full benefit of this new area of opportunity.

Further reading

Visual assessment of marbling and meat colour, Meat Technology Update 2/04, 2004.

'The Role of Marbling in the Eating Quality of Beef' – The Australian Journal of Experimental Agriculture, Volume 44, Number 7, 2004, *pp.* 635-715.

Contents:

Foreword B. M. Bindon *pp*. ii-iii; Dietary fats, marbling and human health, K. Baghurst *pp*. 635-644; The effects of marbling on flavour and juiciness scores of cooked beef after adjusting to a constant tenderness, J. M. Thompson *pp*. 645-652; How might marbling begin? G. S. Harper and D. W. Pethick *pp*. 653-662.

The effects of environmental factors on fatty acid composition and the assessment of marbling in beef cattle: a review, R. K. Tume *pp*. 663-668; The TG5 thyroglobulin gene test for a marbling quantitative trait loci evaluated in feedlot cattle, W. Barendse , R. Bunch, M. Thomas, S. Armitage, S. Baud and N. Donaldson *pp*. 669-674.

Differences in carcass grading schemes used in the USA, Japan and Australia, J. Strong *pp*. 675-680; Objective on-line assessment of marbling: a brief review, D. M. Ferguson *pp*. 681-685.

A review of genetic and non-genetic opportunities for manipulation of marbling, B. M. Bindon *pp*. 687-696; Industry application of marbling genetics: a brief review, P. F. Parnell *pp*. 697-703; Growth, development and nutritional manipulation of marbling in cattle: a review, D. W. Pethick , G. S. Harper and V. H. Oddy *pp*. 705-715.

These papers can be downloaded from the CSIRO Publishing website http://www.publish.csiro.au/nid/73/issue/795.htm for a modest fee.

For more information, contact one of the Meat Industry Services staff listed below.

Food Science Australia Meat Industry Services

Meat Industry Services (MIS) of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia's meat industry.

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