# 17. Marbling


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## Learning Objectives

This lecture describes the development of marbling, the genetic and environmental effects on its level in the muscles and its impact on palatability.
By the end of this chapter you should be able to;

- Understand how marbling fat develops in the carcase
- Know the magnitude and importance of genetic effects on expression of marbling
- Know how marbling impacts on the palatability of beef

## 17.1 Introduction

Marbling is a term used to describe the appearance of intramuscular fat between the muscle fibres in meat. It tends to accumulate in fat cells (adipocytes) located in the interfascicular spaces, embedded in a connective tissue matrix in close proximity to a rich blood capillary network. These adipocytes are distinct from the fat or lipid present within the muscle cells themselves (myocytes). Generally marbling is graded on a visual basis, where the amount of marbling can vary from none to more than 50% of the surface area in highly marbled meat. Under most grading systems higher marbling scores result in improved grading scores. The appearance characteristics of marbling can also affect meat value, with fine, evenly dispersed flecks of white fat (shimofori or snowflake) preferred by Japanese consumers over thick, coarse channels of fat. Marbling can also be assessed using chemical fat extraction, however this is usually reserved for laboratory use.

## 17.2 Development of the adipocyte over time

The intramuscular adipocyte, or marbling fat, is commonly viewed to be a late maturing tissue. However as an animal matures the rate of fat deposition is greater than the rate of lean deposition, therefore the concentration of fat in lean will inevitably increase later in an animal's life. Thus it can be said that the trait (% fat) is late maturing, but this should not be interpreted as intramuscular adipocytes or the intramuscular fat pool itself is late maturing.
The proportional distribution of fat deposition between carcase pools is constant over a wide range of carcase fat contents (ranging from 5 to over 150 kg total fat). Furthermore, the intramuscular fat content has been shown to increase in a linear fashion up to a carcase weight of about 400-420 kg, beyond which there is a plateau. This is further supported by an Australian study (Pethick et al. 2000) showing that fat accretion in the carcase depots (subcutaneous and intermuscular), and within muscle, occur at the same rate through the 304-417kg carcase range (see table 17.1). These results also suggest that the increase in intramuscular fat relies on continued fat synthesis within muscle combined with a decreasing rate of muscle growth

Thus biologically, intramuscular fat is not late maturing BUT the expression of marbling (% fat) is late maturing.

These findings have important ramifications for backgrounding and feedlotting:

1. The sooner an animal reaches its near maximal potential for muscle growth the sooner it would begin to commercially express intramuscular fat.
2. Long feeding periods allow time for muscle maturity to be reached - followed by time for the muscle to fill up with fat.

**Table 17.1. Carcase composition data based on ribset dissection of Angus steers slaughtered at the beginning and end of a 150 day feedlotting period (mean± sem). Source: Pethick et al (2000).**

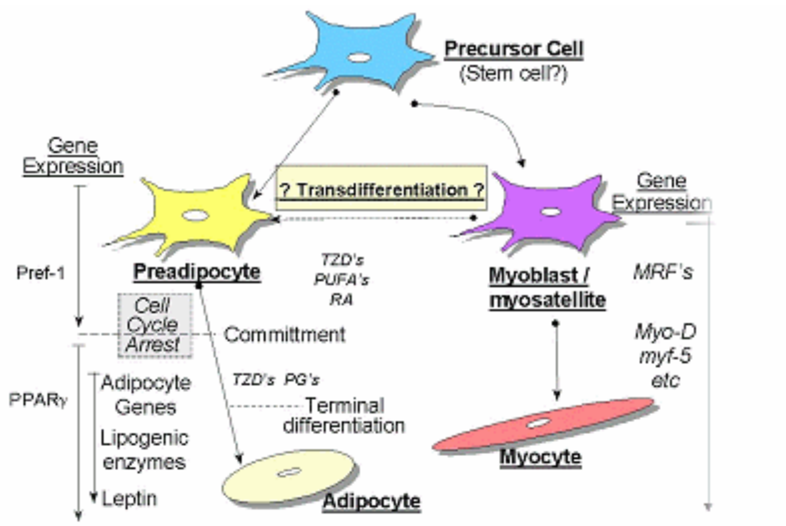
| Carcase attribute | Initial slaughter | Final slaughter | Ratio of final-initial | Significant *P* |
|---|---|---|---|---|
| H.SCW (kg) | 304±5.0 | 417±2.6 | 1.37 | <0.001 |
| Eye muscle area ($cm^2$) | 67±1.6 | 77.3±0.7 | 1.15 | <0.001 |
| Intramuscular fat (%) | 7.01±0.47 | 11.3±0.28 | 1.61 | <0.001 |
| †Total Fat:Bone ratio | 2.65±0.14 | 4.19±0.08 | 1.58 | <0.001 |
| †LT muscle/bone ratio | 0.72±0.03 | 0.78±0.01 | 1.08 | <0.082 |
| †gm fat in LT | 107±7 | 201±6 | 1.88 | <0.001 |
| †LT fat/total fat ratio | 0.021±0.001 | 0.021±0.001 | 1 | ns |
| †LT fat/bone ratio | 0.05±0.004 | 0.09±0.003 | 1.80 | <0.001 |
| † - measured from the ribset dissection | | | | |
| LT = m.longissimus thoracis ns = not significant | | | | |

3. Shorter feeding periods risk failure particularly if there is a relatively short period of fattening after muscle maturity is reached.
4. For the shorter feeding scenario a heavier live weight entry rate would help to secure the required muscle growth.

## 17.3 Development at the cellular level

Development of adipocytes between the fasciculae of skeletal muscle results in marbling (Moody and Cassens, 1968), with these adipocytes likely to be of the white rather than brown adipose tissue type (Moody and Cassens, 1968). Intramuscular adipocytes originate from connective tissue stem cells which, when exposed to particular stimuli will differentiate into pre-adipocytes before proceeding toward adipogenesis. Hence the connective tissue of muscle can be thought of as always having the potential to develop into marbling fat, this development controlled by the presence or absence of various stimulatory or inhibitory factors. The cellular differentiation events that precede development of marbling fat are represented in Fig. 17.1

**Figure 17.1 Overview of stages of adipocyte differentiation. Source: Adapted from Gregoire et al (1998) and Grimaldi et al (1997).**



Overview of stages of adipocyte differentiation showing possible pathway of transdifferentiation of myoblasts into adipocytes. Abbreviations used are pref-1 (pre-adipocyte factor-1), PPAR (peroxisome proliferation-activated receptor gamma), MDFs (muscle differentiation factors), TZDs (thiazolidinediones potent stimulators of the insulin receptor), PUFAs (polyunsaturated fatty acids), PGs (prostaglandins), RA (retanoic acid and metabolites of vitamin A). Adapted from Gregoire *et al*. (1998) and Grimaldi *et al*. (1997).

Another essential component for the development of adipose tissue is microvasculature (see Crandall *et al.,* 1997). The capillary density found within adipose tissue is far greater than that of lean muscle (Gersh and Still, 1945), therefore as marbling increases, capillary density within intramuscular adipocyte clusters would also be expected to increase. Thus it is likely that marbling is closely tied to the regulation of capillary development.

# 17.4 Genetic factors influencing marbling

There is genetic variation associated with intramuscular fat content in beef cattle, hence the trait can be modified through selection. Estimates of the heritability of marbling or intramuscular fat are influenced by the extent to which the animal has been able to express the trait, so care must be taken when assessing relative heritabilities. For example, the method of finish can impact on heritability estimates of intramuscular fat, with one trial indicating that pasture finished animals have heritabilities of 0.30, versus 0.46 for grain finished animals. Obviously the level of marbling is greater in the grain finished cattle. Estimates of heritability also differ between market end points, independent of method of finish. Markets requiring heavier carcase weights demonstrate higher estimates of heritability of intramuscular fat (ie 0.43 for Australian export weight cattle - carcase weight 280-350 kg, versus 0.37 for Australian domestic weight cattle - carcase weight 220 kg).

The potential for marbling also differs significantly between breeds (Olson *et al.*, 1985). *Bos taurus* breeds tend to have higher marbling levels than do *Bos indicus* breeds. Within *Bos Taurus* cattle at the same degree of finish, marbling scores are highest in the dairy breeds (eg Jersey, Friesian), followed by British breeds (eg Angus, Shorthorn, Hereford) and then the European breeds (eg Limousin, Simmental, Charolais) (Table 17.2).

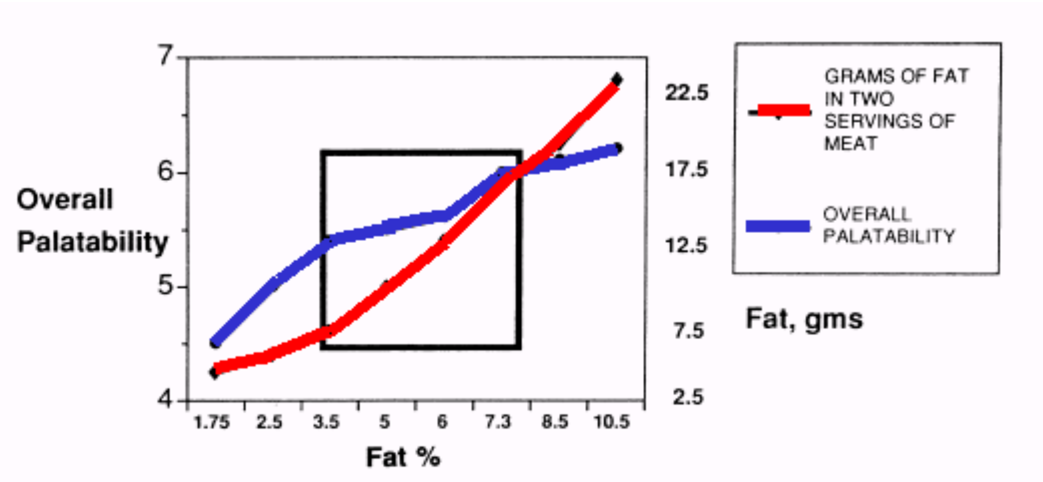
**Table 17.2. Influence of genotype, age and level of feeding on gain and chemical content of the *M. longissimus* – adapted from Trenkle et al., (1978).**

| Sire | Slaughter Wt (kg) | Age (d) | Feed Level | Gain (kg/d) | LD Wt (kg) | Lipid (%) |
|---|---|---|---|---|---|---|
| Charolais | 114.6 | 145 | Milk+Pasture | 0.55 | 1.59 | 0.63 |
| Angus | 110.8 | 136 | Milk+Pasture | 0.56 | 1.52 | 0.91 |
| Charolais | 223.3 | 303 | P+Grower diet | 0.62 | 2.88 | 0.73 |
| Angus | 238.8 | 303 | P+Grower diet | 00.67 | 2.85 | 0.98 |
| Charolais | 367.2 | 389 | Full | 1.31 | 4.63 | 1.88 |
| Angus | 361.8 | 408 | Full | 1.24 | 4.80 | 2.75 |
| Charolais | 361.8 | 457 | Limit | 0.85 | 4.49 | 1.78 |
| Angus | 361.0 | 490 | Limit | 0.72 | 4.90 | 2.60 |
| Charolais | 502.7 | 520 | Full | 1.27 | 6.22 | 3.31 |
| Angus | 503.4 | 572 | Full | 1.03 | 6.01 | 4.87 |
| Charolais | 506.1 | 665 | Limit | 0.84 | 5.93 | 7.64 |
| Angus | 509.7 | 714 | Limit | 0.71 | 5.38 | 12.06 |

# 17.5 Impact on palatability

There has been extensive debate as to the contribution marbling makes to sensory attributes of meat. The Meat Science group at Texas proposed that intramuscular fat was related to palatability although there was a window of acceptability, which inferred that a minimum of 3.5% chemical fat was required in meat.

**Figure 17.2 The window of 'acceptability' for palatability as a function of percentage intramuscular fat in beef muscle. Source: Gardner, (2005).**




However it is not clear whether this window exists for Australian consumers, as the MSA database shows that at the lower levels of palatability there is no evidence of a lower limit for fatness. Table 17.3 shows that for striploin samples from carcases with low Bos indicus content, which had been normally hung and aged for 14 days the effect of marble score resulted in an improvement of eating quality as marble score increased from 0 to 3. However it was interesting that although marbling increased mean palatability score an increase in marble score alone did not guarantee meat quality as even the carcases with a 3 marble score had greater than 10% fail based on the MSA consumer tests. This reinforces the total systems approach to palatability which underpins the MSA grading scheme.

**Table 17.3. The effect of marbling score on the distribution of palatability scores (CMQ4 score) for of striploin samples from carcases which had less than 26% Bos indicus content and the samples were aged for 14 days (MSA database). Source: Perry et al (1999).**

| **Star** | **Aus-MeatMarble Score** | | | |
|---|---|---|---|---|
| **Rating** | **0** | **1** | **2** | **3** |
| Fail | 37 | 21 | 9 | 13 |
| 3 Star | 39 | 42 | 27 | 53 |
| 4 Star | 23 | 32 | 56 | 20 |
| 5 Star | 2 | 5 | 8 | 20 |
| | 100 | 100 | 100 | 100 |

The relationship between marbling and tenderness is variable and may interact with cooking technique. The correlations in Table 17.4 suggest that the advantage in palatability from increased marbling may not be due to tenderness. Alternatively, it appears that as the quality of the meat improves (ie tenderness was addressed) marbling was having an effect via juiciness and flavour, and based on MSA records it had little effect on tenderness. This is consistent with earlier results, which suggested that increased marbling stimulates the salivary glands in the mouth and so the human perception of juiciness increases.

A popular misconception among consumers suggests that meat containing marbling or intramuscular fat is more nutritious because it contains higher levels of mono-unsaturated and polyunsaturated fatty acids whereas in fact, the opposite is true.

**Table 17.4. Correlations between sensory dimensions and marbling score for striploin samples with a range of palatability scores. (40,000 taste panel records from the MSA database) Source: Perry et al (1999).**

| Star | | Palatability | |
|---|---|---|---|
| **Rating** | **Tenderness** | **Juiciness** | **Flavour** |
| No Grade | 0.07 | 0.09 | 0.13 |
| 3 Star | 0.05 | 0.13 | 0.10 |
| 4 Star | 0.02 | 0.22 | 0.21 |
| 5 Star | -0.13 | 0.39 | 0.26 |

. Much of the lipid in lean meat is present in the form of phospholipids (0.5-0.7%), acting as structural components of muscle cell membranes (ie phospholipid bilayer). These phospholipids are highly unsaturated, containing polyunsaturated fatty acids such as C18:2n-6, C18:3n-3, C20:4n-6 and C22:5n-3 representing up to 20% of the total fatty acids. When the fat content of meat increases as with increased marbling, the content of phospholipids does not change significantly as most of the additional lipid is triacylglycerol. These neutral lipids contain more saturated fatty acids and so as marbling increases the proportion of polyunsaturated fatty acids in meat diminishes (Sinclair and ODea, 1987).

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## Readings

There are no readings for this topic.

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## Activities

Available on WebCT

## Multi-Choice Questions

Submit answers via WebCT

## Useful Web Links

Available on WebCT

## Assignment Questions

Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCt

## Summary

Summary Slides are available on CD

- Marbling describes the appearance of intramuscular fat on the surface of muscle, and is a trait that is evidenced during the later stages of maturity as the rate of protein accretion slows.
- The intramuscular adipocytes originate from muscle connective tissue which differentiates in response to certain stimuli.
- Marbling is heritable and is more pronounced in *Bos taurus* breeds as opposed to *Bos indicus*.
- Palatability increases as marbling level increases, and thus marbling represents an important component of the MSA grading system.

## References


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