Learning objectives

The objective is to describe the effect of breed and sex on growth curves, mature composition and the maturing patterns of body tissues. Attention is also given to nutritional and growth path effects on the changes in body composition.

Learning Outcomes

By the end of this chapter you should:

• Know the relative pattern of tissue deposition as the animal matures from birth to maturity
• Understand how the differential pattern of tissue growth in the body impacts on body composition at any weight
• Understand how breeds of different mature size rank in body composition when compared at the same body weight, age and stage of maturity
• Understand how sex effects impact on mature size, composition at maturity, relative rates of tissue deposition and finally comparisons at the same weight and age.
• Understand how castration impacts on mature size, composition at maturity, relative rates of tissue deposition and finally comparisons at the same weight and age.
• Know what impact restricted growth at early or later stages of growth has on body composition of slaughter animals.

7.1 Introduction

The yield of saleable meat produced from a carcase is of prime economic concern to meat processors. Saleable meat comprises the lean trimmed to the customer's requirements, free of bones and excess fat in the carcase. It can be measured as kilograms of product, or expressed as a percentage (usually of cold carcase weight). Weight of trimmed product is overwhelmingly related to carcase weight, with relatively little variation due to other factors, such as fatness, able to be determined. Expressing yield as a percentage, on the other hand, negates the dominance of carcase weight and allows variation in yield due to fatness, muscling and other possible contributing factors, to be discerned.

Berg and Butterfield (1976) considered that the optimal carcase composition was one that had the maximum amount of lean, the minimum amount of bone and an optimal amount of fat. As indicated above the requirement for fat will vary with the market, with some requiring very lean and some very fat product.

To understand the differences in carcase yield it is important to have a thorough understanding of the pattern of development of tissues in the body, as the animal matures from birth to maturity. Whilst most animals are slaughtered at immature stages of development, the concept of mature size is very important in understanding the patterns of tissue growth, in that most animals have similar tissue deposition patterns once the data has been scaled for mature size. This provides a powerful tool to predict the differences in composition that occur when carcases are compared at either the same weight, or at the same age. In addition it is also useful to detect differences that exist between breeds/species that are independent of mature size. These are the differences that are independent of mature size and need to be identified to progress efficiency of production.
Body composition is directly related to carcase composition, which is the main determinant of carcase yield. In the boning room, cuts are removed from the carcase (generally in the boneless form) and the cuts then trimmed to a saleable yield. This yield of trimmed saleable cuts from a carcase is critical to the profitability of a boning room.

### 7.2 Maturation patterns for live weight and body tissues

As the animal grows live weight increases. The relationship between weight and age is generally sigmoidal in shape, as shown in Figure 7.2. The rate of increase in live weight accelerates from birth until a point of inflexion, whereupon it decelerates until the animal reaches maturity. When weight increments are zero, the animal is said to have reached maturity.

In the real world there are many factors that impact on live weight of an animal at any one time and it can often be difficult to see the sigmoidal pattern. Variations in food availability, food quality and environmental conditions will impact on growth, although over the longer term the sigmoidal pattern is usually evident.

**Mature weight (A)**

Mature weight is defined as the live weight an animal attains when it is in equilibrium with its environment, prior to the decline in weight associated with old age. Therefore mature weight is a relative concept that can be influenced by the environmental constraints e.g. nutrition, temperature, activity, disease etc.

Whilst this is a simple concept it is often difficult to use experimentally because one is never sure that animals have finally plateaued in weight and reached maturity. On a high quality ration sheep would be expected to reach their mature size by about 2 to 3 years, whilst cattle may take 3 to 4 years. On a lower level of nutrition this may take longer.

Taylor (1985) stated that mature size was 'the body weight of a normally grown, skeletally mature, normally active adult animal maintained in a state of body weight equilibrium on a standard diet, in a thermo-neutral, disease-free environment with (or adjusted to) a chemical body fat of 20%.'
The relative differences in mature weight are more important than the absolute figures. Therefore in most circumstances animals, within a breed, or between breeds, will rank the same on high or low nutrition. (An exception to this is the genotype x environment interaction that occurs with Bos taurus and Bos indicus cattle).

**Maturing patterns for body tissues**

- Maturing patterns of tissues can be viewed in a graphical form (Figure 7.3) by assessing the rate at which carcase tissues mature relative to the rate at which body weight matures. The final weight and composition of the animal is seen as the final endpoint of growth against which the growth of components is assessed.

**Figure 7.2** Sigmoidal pattern of live weight growth. Source: Thompson, (2006).

**Figure 7.3.** Maturing pattern for body tissues. Source: Butterfield et al (1983a).

Therefore the end-point of growth, or maturity, is said to be 1,1 and immature weights and composition are relative to this end-point.

- Increments in fat weight relative to body weight increase from birth to maturity. Therefore fat is said to have a high growth impetus, or be late maturing relative to body weight.
- Bone has a low growth impetus, or is said to be early maturing, because the increments in bone weight decrease from birth to maturity.
Muscle has an average growth impetus, or is average maturing, as the increments in muscle weight are similar to the increments in body weight as the animal matures. Given the differential pattern of growth for muscle bone and fat as the animal increases in weight (and maturity) the composition of the body would change accordingly, i.e. as the animal matures the proportions of fat increase, bone decreases and the proportion of muscle remains constant.

Breed effects on body composition

*Live weight growth curves*

The live weight growth curves for large and small mature size breeds differ mainly in magnitude, with little difference in shape. Large breeds mature to a greater mature weight and take longer to reach maturity than small mature size breeds. The time taken for an animal to mature is proportional to mature weight (A) raised to the power 0.27. When growth curves for large and small mature size breeds are scaled for mature size, their growth curves can be described by the same curve.

*Mature composition*

A number of studies have examined the composition of mature animals. These studies have found that when animals of different breeds or strains are grown out in the same environment and have achieved their mature size there is little difference in their body composition. This suggests that all animals have a similar end-point in terms of percentage body composition at maturity. This is demonstrated in 2 experiments where cattle and sheep from different breeds or strains were slaughtered at maturity.

Perry et al (2000) conducted an experiment where animals which had been selected for fast and slow growth from birth to yearling were placed in a feedlot and allowed to grow out to maturity. Effectively selection for high or low yearling weight gain resulted in animals which were genetically large and small mature size animals, with the high line having a mature size of nearly 700 kg and the low line 535 kg. When these steers were slaughtered at maturity there was little difference in their body composition.

Table 7.1. Mature weight and percentage composition for steers from lines selected from high and low yearling weight gain. Source: Perry and Arthur (2000). Printed with permission from Elsevier.

<table>
<thead>
<tr>
<th>Tissue Selection Line</th>
<th>Component</th>
<th>Control</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>33.0</td>
<td>32.7</td>
</tr>
<tr>
<td>% Muscle</td>
<td>8.6</td>
<td>8.5</td>
<td>8.4</td>
</tr>
<tr>
<td>% Bone</td>
<td>35.4</td>
<td>33.7</td>
<td>33.7</td>
</tr>
<tr>
<td>Mature Weight (kg)</td>
<td>698</td>
<td>616</td>
<td>535</td>
</tr>
</tbody>
</table>
Butterfield et al., (1983a) conducted an experiment where animals from large and small mature size Merino strains were fed from weaning to maturity (ca. 2 years of age). Animals were slaughtered at regular intervals from weaning to maturity and at maturity. The results showed that at maturity, large and small mature size strains had different weights of tissues, although when expressed as proportions of live weight there was no difference between these strains.


<table>
<thead>
<tr>
<th>Merino Strain</th>
<th>Large Mature Size Merino</th>
<th>Small Mature Size Merino</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Muscle</td>
<td>22.3</td>
<td>22.8</td>
</tr>
<tr>
<td>%Bone</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>%Carcase Fat</td>
<td>23.0</td>
<td>20.5</td>
</tr>
<tr>
<td>Mature Weight (kg)</td>
<td>116.5</td>
<td>90.9</td>
</tr>
</tbody>
</table>

Therefore large and small breeds (or strains) had different mature weights, the same proportional composition at maturity, and a similar pattern of maturity for the different tissues relative to carcase weight. In both of the above experiments there were also immature animals which were slaughtered at regular increments in body weight from weaning to maturity. This allowed the pattern of development for
muscle, bone and fat to be described over the period from weaning to maturity. The results from both studies showed that although the cattle and sheep strains differed markedly in mature weight when the development of the tissues was graphed relative to the development of the body (as in Figure 7.3) there was no difference between the strains, i.e. fat, muscle and bone matured at the same rate regardless of strain.

**A model to describe changes in body composition**

Given the same compositional end-point and similar patterns of maturity for tissues in the large and small breeds, the changes in composition for all breeds can be described by the one graph. This graph shows that as the animal progresses from birth to maturity there is a decrease in the percentage of bone, a slight decrease (or no change) in the percentage of muscle, and a large increase in the percentage of fat.

In effect this provides a model by which we can compare body composition between all breeds, regardless of mature size.

**Figure 7.5. Changes in percentage body composition as a function of stage of maturity.**

*Source: Thompson, (2006).*

### 7.3 Comparison between large and small mature size breeds

Animals from different breeds are usually compared

- at the same weight
- at the same age
- at the same stage of maturity

**Comparison between large and small breeds at the same live weight**

In the example below when cattle were killed at 300 kg live weight, the large mature size breed would be 60% mature, whilst the small mature size breed would be 75% mature. When these stages of maturity were superimposed on the body composition graph it can be seen that the large mature size carcasses would be less mature and therefore would be expected to have less fat, a slightly greater proportion of muscle and a greater proportion of bone than the small mature size breed.
Comparison at the same age

In the example below when cattle were killed at 100 weeks the large mature size breed would be 80.9% mature, whilst the small mature size breed would be 83.3% mature. When these stages of maturity were superimposed on the body composition graph in it can be seen that the large and small mature size breeds still ranked the same as for the previous comparison, but the magnitude of the differences were substantially less. Therefore at the same age the large mature size carcases would be expected to have slightly less fat, a similar proportion of muscle and a slightly greater proportion of bone than the small mature size breed.

Figure 7.7. Growth curves for a) large and small mature size breeds and b) comparison of body composition at the same age. Source: Thompson, (2006).
Comparison at the same stage of maturity

In the example below when cattle were killed at 80% of their mature size the large mature size breed was heavier and older compared to the small mature size breed. When these stages of maturity were imposed on the body composition graph it can be seen that large and small mature size breeds have the same body composition.

Figure 7.8. Growth curves for a) large and small mature size breeds and b) comparison of body composition at the same stage of maturity. Source: Thompson, (2006).

Experimental results which have compared breeds at the same weight, same age, or the same stage of maturity.

The above comparisons are valid examples of what happens commercially. From the butchers perspective the comparison at the same weight is relevant, whilst if the producer is constrained by a rapid seasonal cut-offs, comparison at the same age is relevant. If the feed supply is not constrained by season then producers tend to turn animals off at the same stage of maturity (i.e. large mature size breeds are turned off when they are heavier and older but they are at the same composition, and therefore have the same percentage carcase yield).

Figure 7.9 below (adapted from Kempster, Cuthbertson and Harrington 1982) demonstrates the above effects using dissection results from a number of experiments. When breeds were compared at the same weight, differences in the percentage of meat in the carcase were of the order of 10% (with the large mature size breeds being less mature so a greater percentage of muscle in the carcase). However when the same data were reanalysed to compare the breeds at the same age, the ranking of the breeds was similar, but the magnitude of the differences smaller. Finally if the breeds were compared at the same percentage of fat in the body (or the same stage of maturity) there was little difference between the breeds in percentage of muscle in the carcase.
Figure 7.9. Meat yields from carcases of crossbred cattle by different sire breeds. Source: Kempster, Cuthbertson and Harrington (1982).

Clay Centre data (236) with MLC data (209) for comparison. Key: AA Aberdeen Angus; AxH Aberdeen Angus x Hereford; CH Charolais; J Jersey SD South Devon (Kempster, Cuthbertson and Harrington 1982).

### 7.4 Sex effects on body composition

Sex effects can be viewed using the same concepts of mature weight, mature composition and maturing patterns for individual tissues.

**Entire males vs females**

Rams and bulls have a greater mature size than ewes and cows, respectively. The ratio of entire male to female mature weights in both cattle and sheep is of the order of 1.4. In addition to differences in mature weight, mature composition between sexes also differs, in that males have less fat, more muscle and more bone than females at maturity (see table 7.3 below). Further, the rate at which the tissues mature relative to the rate at which the body matures also differs between sexes, with muscle being later maturing in rams and fat being later maturing in ewes.

**Table 7.3. Mature body composition in rams and ewes.**

*Source: Thompson Butterfield and Perry (1985).*

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rams</td>
</tr>
<tr>
<td>% Muscle</td>
<td>26.7</td>
</tr>
<tr>
<td>% Bone</td>
<td>6.3</td>
</tr>
<tr>
<td>% Fat</td>
<td>29.5</td>
</tr>
<tr>
<td>Mature Live Weight (kg)</td>
<td>70.0</td>
</tr>
</tbody>
</table>

The difference in mature composition and maturing pattern for the various tissues means that the relative composition of rams and ewes changes depending upon the live weight, or stage of maturity at which the comparison is made (see Figure 7.10 below).
Figure 7.10. Changes in the percentage of dissectible fat in the body of Merino rams and ewes (a) relative to live weight, and (b) stage of maturity during progress to maturity. Changes in the percentage of muscle in the body of Merino rams and ewes (c) relative to live weight, and (d) stage of maturity during progress to maturity.


The above graph shows that at the lighter body weight rams and ewes have a similar percentage fat, although as fat matures more rapidly to a higher percentage fat at maturity the difference between sexes in body composition changes rapidly as body weight increases.

**Entire males vs castrates**

Castration of entire males is commonly undertaken in Australia, Britain and North and South America. This contrasts to pigs where in Australia males are left entire. Also to much of Europe, where entire cattle are often used for meat production. Historical reasons for castration include the increased fattening ability of the castrate. In addition it was often used as a management aid and allowed controlled breeding.

**Table 7.4. Mature composition of rams and wethers** Source: Butterfield et al (1983a).

<table>
<thead>
<tr>
<th>Tissue Component</th>
<th>Mature Composition</th>
<th>Rams</th>
<th>Wethers</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Muscle</td>
<td></td>
<td>24.8</td>
<td>22.9</td>
</tr>
<tr>
<td>% Bone</td>
<td></td>
<td>4.7</td>
<td>4.2</td>
</tr>
<tr>
<td>% Carcase Fat</td>
<td></td>
<td>24.8</td>
<td>30.0</td>
</tr>
<tr>
<td>Mature Weight (kg)</td>
<td></td>
<td>99.7</td>
<td>95.9</td>
</tr>
<tr>
<td>Head Plus Horns (kg)</td>
<td></td>
<td>6.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Testes (kg)</td>
<td></td>
<td>0.3</td>
<td>–</td>
</tr>
</tbody>
</table>
Table 7.4. Mature composition of rams and wethers. Source: Butterfield et al. (1983a). shows that after adjustment for the increased weight of the head and horns and testes in the rams, rams and wethers had a similar mature weight, although there were large differences in mature composition. At maturity, rams had less fat and more bone and muscle than wethers. Also there was no difference in maturing patterns for muscle, bone and fat. Because there was no difference in mature size, comparisons were similar whether they were made at the same stage of maturity, or body weight. Rams were leaner than castrates at all stages, with the magnitude of the difference increasing with increased live weight (or stage of maturity).

7.5 Manipulation of body composition by nutrition/ growth path.

Nutrition
Carcase composition can be readily manipulated in non-ruminants. However in ruminants the effect of fermentation in the rumen and the production of volatile fatty acids (Fas) and microbial protein has a large modifying effect on the nutrient supply to the lower digestive tract and makes manipulation of body composition difficult. However it is possible under controlled feeding to modify body composition by either nutrition, or growth path.

The above concepts in Figure 7.11 below have been largely derived from experiments with milk-fed lambs, or with monogastrics. In principle the concepts are applicable to ruminants if the nutritional treatments are a reflection of what is delivered to the lower digestive tract.

Figure 7.11. Modification of body composition under controlled feeding

(a) High growth rate (A) versus lower growth due to feed restriction (B); animals at A will generally be fatter than at B.

(b) Parallel growth paths but different diets: animals fed on pasture (→) contained less fat than grain-fed (→•) animals at the same weight.

(c) Periods of high (H) and low (L) growth: at the same age and weight, animals from the L-H path were fatter than those from the HL path.
Growth Path

Growth path does have an effect on composition. However the results from a number of experiments appear to be contradictory, whereby sometimes slower growth increases fatness, whereas in other experiments it has no effect and yet in others it decreases fatness. Recently work at the CRC placed these results into a model which helps explain these apparently contradictory effects.

The following Figure 7.12 shows the pattern of fat deposition in continuously grown well fed steers. As weight increases both protein and fat increase although fat increases at a faster rate.

In Figure 7.13 steers are restricted late in life and both protein and fat deposition are constrained. After ‘late restriction’ protein growth returns to normal, although fat growth does not. At slaughter these steers will be leaner than normally grown steers.

In Figure 7.14 steers are restricted early in life. After ‘early restriction’ protein gain may not catch up, whilst fat deposition may commence prematurely and at slaughter these animals will be fatter than normally grown steers.

Figure 7.12 The growth pattern of fat and protein in the carcase of steers with an uninterrupted growth pattern from weaning to slaughter. Source: Thompson, (2006).

Figure 7.13. The effect of nutritional restriction on late growth periods on body composition at slaughter. Source: Thompson, (2006).
In Figures 7.15 to 7.19 the effect of growth restriction in utero (resulting in low birth weight), pre-weaning, post weaning, and during finishing, integrated from several CRC experiments, is summarised. These uphold the theory that slow backgrounding growth can result in animals that grow faster during finishing, and produce leaner carcases. Slow growth rate prior to weaning, however, does not necessarily result in increased fatness when compared at the same carcase weight, although it does have a lasting effect on final carcase weight. The apparent contradiction with the previous section may be more due to what the animals eat, rather than how much, i.e. the energy density of the diet. Severe restriction to weaning followed by high energy feed (concentrate) from weaning to slaughter may result in fatter carcases (at the same weight), compared to those from well grown cattle, but this difference is not evident when grown out on pasture post-weaning (Tudor et al. 1980).

Figure 7.14. The effect of nutritional restriction on early growth periods on body composition at slaughter. Source: Thompson, (2006).

Figure 7.15. In utero growth restriction results in slow growth rates and therefore reduced carcase weight at later ages, but does not affect final body composition. Source: Greenwood et al (2006).
Figure 7.16. Restricted pre-weaning growth affects final carcase weight, but not final composition. Source: Greenwood et al (2006).

![Diagram showing effects of restricted pre-weaning growth](image)

- Slow pre-weaning growth
- Pre-weaning - 70kg
- Grow-out
- Finishing - 40kg
- 30 mths

- Some compensation during backgrounding
- Similar feedlot growth performance
- Calves don’t catch up in weight
- No adverse effect on composition
- No adverse effect on eating quality

Figure 7.17. Growth restriction at weaning affects final carcase weight, but does not affect final carcase composition. Source: Greenwood et al (2006).

![Diagram showing effects of growth restriction at weaning](image)

- Growth restriction around weaning
- Finish on pasture (Qld)
- Live weight
- Age

- Wean
- Pre-weaning
- Grow-out
- Finishing - 50 kg
- 30 mths

- Loss (or slow gain)
- 4 months
- - 140 kg

- Partial compensation
- “Never catch up” in weight
- Similar fatness at slaughter
- No adverse effect on eating quality
Figure 7.18. Growth restriction during backgrounding can result in compensatory growth during finishing, with no effect on carcase weight (if finishing long enough for complete “catch-up” to occur), and can result in leaner carcases.

Figure 7.19. Fast growth rate during backgrounding can result in fatter carcases. Source: Greenwood et al (2006).
Summary

Summary Slides are available on web learning management systems

Breed differences
- often breeds differ in mature size
- breeds have the same percentage composition at maturity
- there is no difference between breeds in the rate at which muscle, bone and fat mature relative to total body weight
- therefore breed effects on composition largely reflect differences in the stage of maturity at which the comparisons are made, rather than breed differences per se.

Sex differences

Entire males vs females
- entire males have a greater mature weight than females
- sexes differ in mature composition; entire males have less fat, more muscle and more bone than females.
- there is a difference between the sexes in the rate at which tissues mature relative to total body weight
- therefore sex effects on body composition tend to vary depending upon the stage of maturity or body weight at which the comparison are made.
- Entire males vs castrates
- entire males and castrates tend to have similar mature weights
- entire males and castrates differ in mature composition; entire males have less fat and more muscle and bone than castrates
- there is no difference between entire males and castrates in the rate at which tissues mature relative to total body weight
- therefore differences between entire males and castrates depends upon the body weight (or stage of maturity) at which the comparisons are made.

Growth path effects on body composition

The effect of growth restrictions on body composition depends upon the time of restriction and energy density of the subsequent diet.
- early growth restriction will reduce both protein and fat.
- after ‘early restriction’ protein gain may not catch up, whilst fat deposition may commence prematurely - at slaughter these animals will be fatter than normally grown steers. This is more likely to happen if the postweaning diet is energy dense.
- early growth restriction followed by normal growth at pasture will not necessarily have any effect on final fatness, when compared at the same carcase weight with animals that were not restricted.
- late restriction also reduces both protein and fat. After ‘late restriction’ protein growth returns to normal, although fat growth does not. At slaughter these steers will be leaner than normally grown steers result in fatter animals.
References
MLA Fact Sheet: MSA requirements for handling cattle

Glossary of terms
<table>
<thead>
<tr>
<th>Mature weight</th>
<th>the weight an animal reaches when it is in equilibrium with its environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point of inflexion</td>
<td>when the growth rate changes from accelerating to decelerating rate</td>
</tr>
</tbody>
</table>