# THE CARCASS COMPOSITION AND MEAT QUALITY OF MALE FALLOW DEER

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## ABSTRACT

Fallow deer (Dama dama) are rapidly gaining in popularity in New Zealand as a farmed species for venison production. Subjective observations suggest that venison from fallow deer up to 2 years of age has the desirable 'leaness' characteristic. The main objective of this study was to investigate relationships between carcass weight (20-40 kg), age (13, 17 and 25 months), season of slaughter (summer vs. early winter) and aspects of carcass quality in male fallow deer.

Groups of male fallow deer raised on pasture near Te Puke (8 animals per group) were slaughtered at approximately 13 months (mid January), 17 months (late May), and 25 months of age (mid January). Average liveweights and carcass weights at slaughter were 43 and 25 kg at 13 months (M13), 47 and 28 kg at 17 months (M17), and 60 and 36 kg at 25 months of age (M25). Dressing-out percentage increased from 58.6 to 61.8% over the liveweight range of 41 to 66 kg.

The pattern of tissue growth with increasing liveweight was similar to that exhibited by other meat-producing ruminants. Allometric growth coefficients for the four dissected components relative to carcass weight were: muscle, 0.85; bone, 0.62; intermuscular fat, 1.61 and subcutaneous fat, 2.85.

Percentage total fat in the carcass was 7.8% in M13, 9.4% in M17 and 12.3% in M25 bucks. Low fat contents were accompanied by a high percentage of muscle in the carcass, 74.3% in M13, 71.5% in M17, 70.1% in M25, and hence high muscle to bone ratios (mean = 5.5).

The mean proportion of the carcass in each commercial cut was neck, 12.6%; flank, 15.4%; shoulder, 17.8%; saddle, 15.5% and haunch, 39.4%. Allometric growth coefficients for the 5 commercial

cuts relative to side weight were neck, 1.02; flap, 1.33; shoulder, 0.87; saddle, 1.04 and haunch, 0.91.

With increasing carcass weight minor relative redistribution of muscle, fat and bone across the carcass cuts was detected. The decrease in the relative proportion of the carcass in the primal haunch cut was due solely to a decrease in the proportion of bone in the cut. The allometric growth coefficient of bone in the haunch relative to total side bone was 0.76. The saddle was the major site for subcutaneous fat deposition with increasing carcass weight. The allometric growth coefficient of subcutaneous fat in the saddle relative to total side subcutaneous fat was 1.26. The flank was the major site for intermuscular fat deposition with an allometric growth coefficient of 1.29 relative to total side intermuscular fat.

There were no differences in the proportions of the total dissected tissues between group M17 (slaughtered in early winter) and groups M13 and M25 (slaughtered in summer) other than could be explained by differences in carcass weight. However, the proportion of total muscle weight in some individually weighed haunch and neck muscles were consistently lowest and highest respectively in the M17 group.

The chemical composition of the dissected tissues and some individual muscles was determined. The percentage water in the muscle tissue of the M17 group was lower and the percentage protein higher than in groups M13 and M25. The lipid percentage of the fat depots was low (subcutaneous, mean = 58%; intermuscular, mean = 47%).

Carcass weight explained 81% of the variation in carcass fat. Fat-depth 'C' and kidney fat weight explained a further 10.3 and 11.3% respectively, of the total carcass fat variation.

Meat quality characteristics measured were colour, ultimate pH, tenderness and water-holding capacity.

The major meat quality differences were between group M17, and groups M13 and M25. Meat colour was darker and water-holding capacity greater in Groups M13 and M25. This was attributed primarily to differences in conditions at slaughter.

Warner-Bratzler shear (tenderness) values averaged 3.73 kg and 4.68 kg for the mm. longissimus and semimembranosus respectively. These values were lower than those reported for sheep and cattle.

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# Chapter 1

## INTRODUCTION

Exports of New Zealand feral venison began in 1958 as a by-product of culling operations to control noxious animals (Clouston, 1974). Deer farming was legalised between 1967 and 1969 and during the 1980's it has increased greatly.

Early venison exports were largely to West Germany where venison is a traditional game meat. More recently markets have also been established in Australia, Asia and the United States. Ante-mortem and post mortem inspection certification for farmed venison has given access to a number of these new markets.

Venison is known for its lean qualities and it compares very favourably in this regard with other farmed red-meat-producing species.

The fallow deer (Dama dama) is the second most numerous farmed deer species in New Zealand, following behind the red deer (Cervus elaphus). In 1984 approximately 14 000 fallow does and 7000 fallow bucks were being farmed (Agricultural Stats, 1984).

Several reasons exist for fallow deer being less popular than red deer. The first, and probably the most important reason, is that the fallow feral populations, from which all farmed stock were initially captured, are smaller and less widespread across the country than those of red deer. A second reason is that fallow velvet is of low value. Finally behavioural characteristics of the fallow deer can make them more difficult to manage under farming practice. A further more recently documented disadvantage of fallow has been their poorer

reproductive performance (Asher & Gregson, 1983). This may also have been a source of discrimination against the species. However, a number of farmers have chosen fallow deer in preference to red for reasons such as the lower cost per breeding stock unit and the convenience of nearby feral populations.

The Australian restaurant trade, a large export market for New Zealand venison, now buys largely fallow venison in preference to red on the grounds of its higher eating quality and the greater versatility of the smaller cuts. The smaller mature weight of fallow deer (about 35% that of red deer) may also be an advantage in certain farming environments, for example hill country or in wet environments where pasture damage readily occurs. This suggests considerable potential for the farming of the species.

Apart from the subjective assessments of consumers very little information is available on meat quality aspects of fallow deer. There is also little information on growth of the main carcass tissue components relative to age, liveweight or season of slaughter in fallow bucks. Such information would be useful to the industry in determining desirable carcass weight ranges and times for slaughter to achieve a high quality product with minimum carcass fat.

The main objective of this study was to investigate the effect of carcass weight (20-40 kg), age (13, 17 and 25 months) and season of slaughter (summer vs. early winter) on aspects of carcass and meat quality in male fallow deer.

The specific aspects of carcass and meat quality considered were:

(1) Dressing-out percentage, and tissue (muscle, fat, bone) and chemical (water, lipid, ash, protein) composition;

(2) Tissue distribution between the commercial venison cuts;

(3) Meat quality characteristics including tenderness, colour, water-holding capacity and pH of muscle tissue.

A secondary objective was to quantify the growth of other variables such as organ weights and m. longissimus areas in an attempt to provide some base data for the species. In addition the use of simple measurements to predict carcass composition was examined.

# Chapter 2

# REVIEW OF LITERATURE

## 2.1 INTRODUCTION

Limited information on growth patterns and the tissue composition of growth exists for deer species. However that which does exist, suggests both similarities and differences from patterns for other meat-producing ruminants. In this chapter the characteristic liveweight growth pattern exhibited by temperate deer species is discussed in relation to that occurring in other meat-producing ruminants. General patterns of tissue growth (muscle, fat and bone) in deer and other domestic ruminants are described. Finally aspects of meat quality which determine the consumer acceptance and eating quality of muscle tissue are presented.

## 2.2 PATTERNS OF LIVEWEIGHT GROWTH

### 2.2.1 Introduction

The liveweight growth pattern of meat-producing animals determines the potential edible tissue available at any point in time. Liveweight growth patterns for various breeds and crosses of domestic sheep and cattle are well documented. Studies to determine similar information for deer species have become more numerous in recent years. These liveweight growth patterns are discussed in this section.

### 2.2.2 General Pattern of Liveweight Growth

The general pattern of liveweight growth by animals to maturity was characterised by Brody (1928) as a sigmoid curve. This pattern is similar for all meat-producing species which differ only in mature

weight and the time taken to reach maturity (Brody, 1945; McMeekan, 1959). Growth initially proceeds at an accelerating rate with time until an inflection point is reached, and then slows to cease at a mature weight. Brody (1945) considered the point of inflection generally corresponds to the attainment of puberty. This occurs between 30 and 50% of mature liveweight (von Bertalanffy, 1957).

### 2.2.3 Liveweight Growth Patterns in Deer

As with other species the growth in bodyweight of temperate deer species is characterised by a phase of exponential growth for the first 3-4 months of life. However in deer this is followed by a complex pattern of seasonal gain and loss in weight, superimposed upon a gradual net increase until mature size is reached (Thompson et al., 1973; Blaxter et al., 1974; Moore & Brown, 1977; McMillin et al., 1980; Warren et al., 1981; Plotka et al., 1981; Ryg, 1982; Ryg & Jacobsen, 1982a; Ryg & Langvaten, 1982).

This cyclical growth pattern occurs despite the constant availability of a nutritionally adequate ration (Wood et al., 1962; Bandy et al., 1970; Norden et al., 1970).

The point of inflection in the growth curve of fawns has been shown to correspond with the onset of puberty in some deer species. This point occurs around 25% of mature weight (Wood et al., 1962; Norden et al., 1970). Following puberty lower liveweight gains have been reported until the onset of spring (Wood et al., 1962).

Beyond puberty liveweight gains in entire male deer decrease markedly and after the first or second year of life they usually become negative during the winter. This phase of negative growth is

followed by a phase of rapid growth in spring which slows in autumn to be followed by another negative phase in winter. The growth curves described by Wood et al. (1962) for black-tailed deer (Odocoileus hemionus) are similar in form to a number of other deer species (Moen, 1978) and are depicted in Fig. 2.1.

Wood et al. (1962) used four distinct curves to describe these growth patterns in black-tailed deer. One to describe prepubertal growth (b); a second the actual course of weight change through the annual cycle of growth rate (a); the third described the annual progression of maximum weights reached (d); and the fourth the progression of minimum weights reached (c) (Fig. 2.1). Curves d and c most closely conform to the standard descriptions of animal growth.

The oscillations in liveweight are tied very closely with the sexual cycle in deer. In males the summer period of rapid liveweight gain terminates with the maturation of the antler, the loss of velvet, enlargement of neck muscles and maximum testis diameters (Bandy et al., 1970; Plotka et al., 1981). The subsequent weight loss is associated with rutting behaviour and then a falling or static liveweight through the winter months.

The magnitude of each successive annual weight loss appears to increase until maturity is reached (Bandy et al., 1970). In mature male deer minimum liveweights reached during the winter appear to be close to true lean body weights. Such low levels of body fat do not occur in young males (Bandy et al., 1970).

Female deer show a similar liveweight pattern to males throughout the year, but very much reduced in terms of amplitude of liveweight gain and loss. Minimum and maximum weights are reached about the same

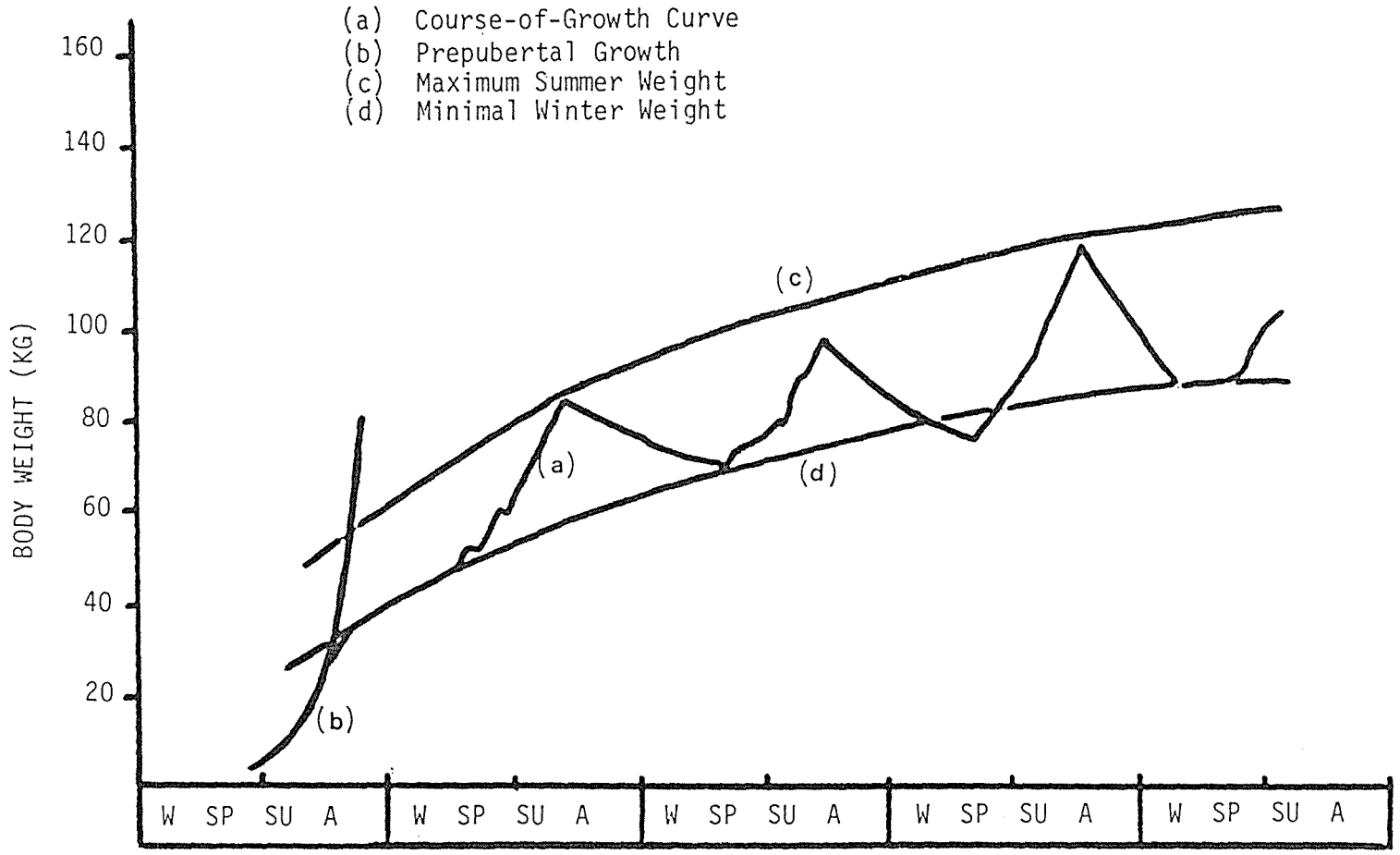


Figure 2.1. Growth curves for a representative male of Odocoileus hemionus hemionus (adapted from Wood et al., 1962). W = winter, SP = spring, SU = summer, A = autumn.

dates as for males but pregnant females begin gaining weight earlier in the spring (Hoffman & Robinson, 1966; Bandy et al., 1970; Moen, 1978).

The pattern for the castrate appears to be similar to the female. The castrate does not appear to reach the same liveweight as the entire in late summer but also does not drop as low over the winter months (Ryg & Jacobsen, 1982b).

## 2.3 PATTERNS OF TISSUE GROWTH

### 2.3.1 Introduction

The liveweight growth curve represents the sum of the individual growth curves of the tissues and organs that make up the body. These tissues and organs each have different growth curves with different periods of maximum growth (Hammond, 1960).

Thus while some tissues and organs are relatively well developed at birth, others reach mature proportions later in life, and still others develop at a proportionately similar rate to the total body mass (Hammond, 1932; Palsson, 1955; McMeekan, 1959).

A method which has been widely used to examine the relative growth patterns of the carcass and body components is the allometric equation of Huxley (1932). The relationship between the measurement of a part (y), and that of the whole body or another part of it (x) can be described by use of the allometric equation $y = ax^b$, where a and b are constants. The exponent b was described by Huxley as the allometric growth coefficient and represents the ratio of the percentage growth rate of y relative to that of x. In its logarithmic form it becomes linear; $\ln y = \ln a + b \ln x$.

Allometric growth coefficients have been used to describe and contrast the proportional changes in the various carcass and body components (y) relative to the total carcass (x). The theory associated with this formula implies that the form of an animal depends solely on its absolute size or weight and not on the length of time taken to reach that size (Seebeck, 1968).

A number of researchers have expressed reservations about the use of the allometric equation (e.g. see Walstra, 1980) but it remains a useful tool in body composition studies (Seebeck, 1968).

In the next two sections general tissue growth patterns in domestic animals are discussed. Tissue growth patterns specific to deer are discussed in section 2.5.

### 2.3.2 Patterns of Tissue Growth in Domestic Animals

#### 2.3.2.1 Muscle, fat and bone

Growth studies with sheep, cattle and pigs have largely concluded that for any given animal of a particular breed or sex fed an adequate level of nutrition, the tissue growth patterns tend to be weight dependent. That is each tissue tends to reach a specific weight at a given carcass weight (Berg & Butterfield, 1975).

The mature weight of the animal to a large extent determines the tissue composition at a given weight. From studies with sheep, cattle and pigs the order of development of the commercially important body tissues from earliest to latest has been determined as: bone, muscle, kidney fat, intermuscular fat, subcutaneous fat, intramuscular fat (Palsson & Verges, 1952; Palsson, 1955; McMeekan, 1959).[1]

[1]Recent evidence has suggested that kidney fat has a period of rapid growth later in life, which may explain some of the conflicting results in the studies regarding the relative growth of this depot (Kempster, 1981).

The early developing tissues, such as bone, represent a higher proportion of the carcass at birth than at later stages and conversely for the fatty tissues which are later developing. In terms of growth relative to the carcass from birth until maturity muscle increases proportionately more than bone. Fat tissue initially appears to increase slowly then increases at a greater rate than muscle. So muscle percentage of the carcass first increases and then when a certain stage of development is reached, muscle percentage decreases. Fat percentage continuously increases and bone percentage continuously decreases. These relative tissue growth patterns are depicted in Fig. 2.2. For example, allometric growth coefficients for the tissues in Fig. 2.2 would be just less than 1.0 for muscle and bone and between 1.5 and 2.0 for fat.

#### 2.3.2.2 Body organs

As the internal organs are essential for the assimilation of the materials necessary for growth they logically proceed towards their mature weight earlier than the body as a whole. Generally they have been found to be earlier maturing than such structures as carcass muscle and bone (Butterfield et al., 1983a) or individual muscles within the musculature (Butterfield et al., 1983b), growing proportionately slower than body weight (Brody, 1945). However, there appears to be a wide range of maturing patterns followed by the body organs. The brain, eyes and spinal cord have been found to be extremely early maturing (Kirton et al., 1972; Butterfield et al., 1983c), which is in agreement with Palsson's (1955) observation that nervous tissue is one of the earliest developing body parts. They

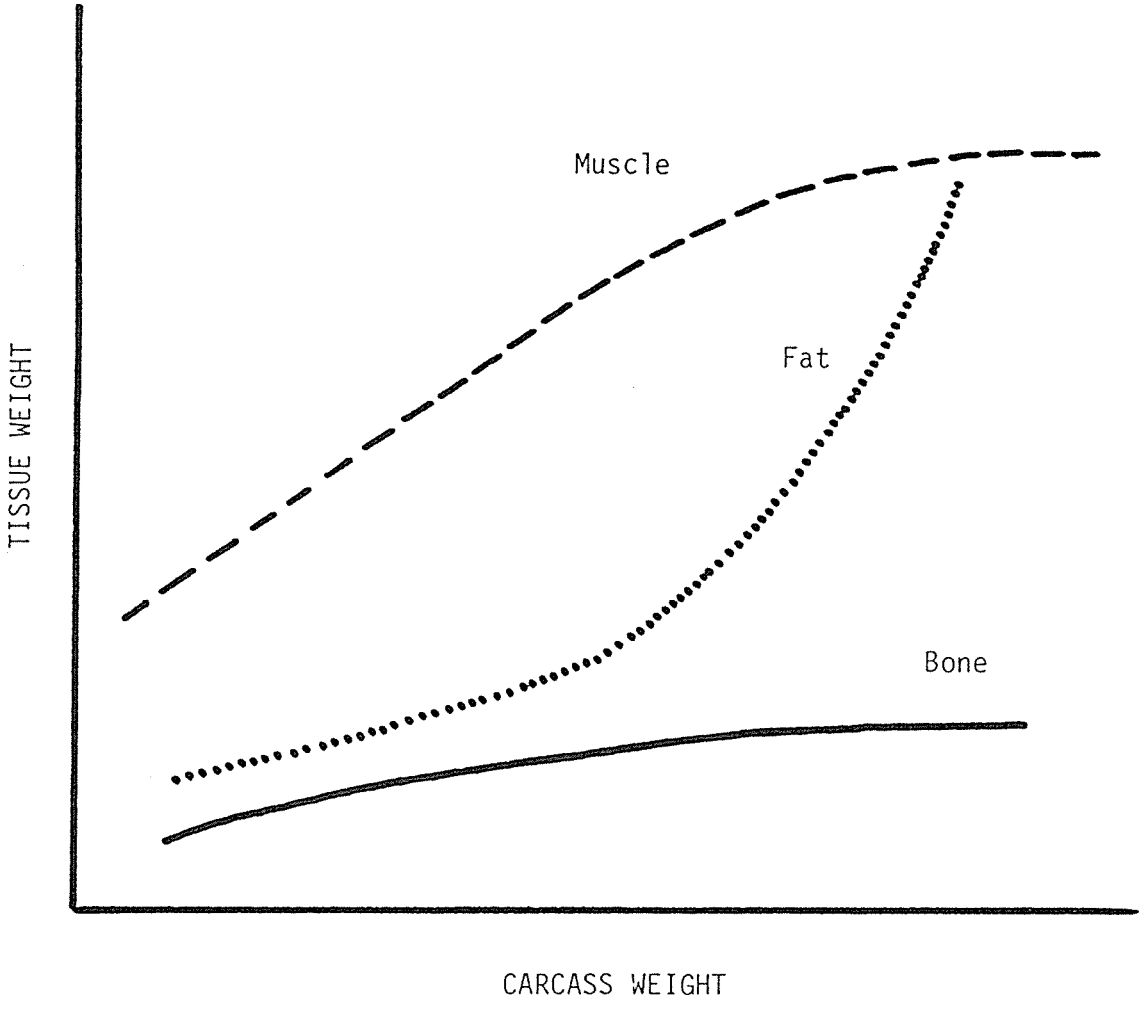


Figure 2.2. Schematic representation of tissue growth patterns relative to carcass weight (adapted from Berg & Walters, 1983).

remain below, but close to their mature weights throughout much of the maturing process. Other less early maturing organs, such as the lungs, liver and portions of the digestive tract achieve their mature weight when the animal is between 40 and 80 percent mature, whereas most organs, such as the heart and kidney, continue to increase in weight up to maturity of the whole animal (Butterfield et al., 1983c).

These growth patterns do, however, differ between species because of differences in the stage of development at birth and functional demands, and they differ within species owing to the effects of physical training (Walstra, 1980). Generally the organs which are most necessary for survival are earlier maturing.

### 2.3.3 Factors Influencing Tissue Growth Patterns

Factors which alter the general pattern of relative tissue growth, as depicted in Fig. 2.2, are of importance in commercial meat production where the efficiency of an operation is determined by the yield of edible product per unit time. These factors are discussed in the following sections.

#### 2.3.3.1 Age and weight

The growth patterns in Fig. 2.2 tend to be weight dependent rather than age dependent (e.g. Berg & Butterfield, 1975). Animal age, within limits, has very little influence on tissue growth patterns.

#### 2.3.3.2 Breed

The mature weight of an animal has a major influence on its composition at a given weight or age (Kempster et al., 1982). Animals

with heavier mature weights normally have higher growth rates and take longer to mature (Kempster et al., 1982). As growth proceeds to mature weight there is a shift in the emphasis from bone and muscle growth to fat deposition. Animals with lighter mature weights partition more of their available energy intake into fat growth at a given age (Berg & Butterfield, 1976) and are thus termed earlier maturing. Hence for early maturing breeds the line for fat growth in Fig. 2.2 is shifted to the left, for late maturing breeds it is shifted to the right. Kempster et al. (1982), however, emphasised that although a clear inverse relationship exists between growth rate and rate of maturity between extremes in mature body weight, there are differences in growth curves between breeds of more similar mature weights which disturb the relationship. They illustrated this point by comparing the Friesian and Hereford breeds. The Friesian grows relatively slower and fattens later than would be expected from its mature weight in comparison with the Hereford. Breed differences also exist with respect to the rate of fat deposition and the ultimate proportion of fat tissue at mature weight (Berg & Butterfield, 1975).

The growth of muscle relative to bone has also been found to be under genetic influence which gives rise to breed differences in muscle to bone (M:B) ratio (Fourie et al., 1970; Davies, 1974; Berg et al., 1979a, d). Genetically high muscle to bone ratios are apparent early in the post-natal period and are maintained throughout life. In Fig. 2.2 the line for muscle growth of a heavily muscled breed would be above that shown for the average animal and the line for bone growth would be lower.

'Double-muscled' cattle have bone growth slower than average, muscle growth much faster than average and little fat deposition. This results in an animal with a desirably high M:B ratio but unfortunately structural and functional unsoundness (Berg & Butterfield, 1976).

#### 2.3.3.3 Sex

The effect of sex on the tissue growth patterns can largely be explained by differences in mature body weight between the sexes. Thus bulls with heavier mature weights grow faster than heifers and fatten at heavier weights, with steers being intermediate (Breidenstein et al., 1963; Prescott & Lamming, 1964; Bradley et al., 1966).

#### 2.3.3.4 Nutrition

The classical theories developed by the Cambridge school (Hammond, 1932; McMeekan, 1940a, b, c; Palsson & Vergés, 1952; Palsson, 1955) are no longer held in favour. These briefly stated that a period of restricted nutrition during growth differentially affected the various tissues and parts of the body, depending on their stage of development during the period of under-nutrition. However plane of nutrition has been demonstrated to effect the fattening pattern in cattle and pigs (McMeekan, 1940a, b, c; Callow, 1961; Richmond & Berg, 1971; Davies et al., 1980), and to a lesser extent in sheep (Searle et al., 1972).

The picture with the muscle and bone components is not as clear. Current evidence supports the view that restricted nutrition causes a more or less uniform retardation of development except insofar as fat

tissue is concerned (Wallace, 1948a, b, c; Wilson, 1952, 1954, 1958; Elsley et al., 1964). There is some evidence that a high plane of nutrition produces carcasses with higher fat content at any given weight (Berg & Walters, 1983).

The protein content of the diet has also been found to influence the composition of growth (Black, 1974). Low levels of protein in the diet have been associated with higher proportions of fat in the body tissue gain.

## 2.4 DIFFERENTIAL GROWTH WITHIN TISSUES

### 2.4.1 Introduction

Differential growth patterns within body tissues, as described by McMeekan (1940a, b, c) for pigs and Palsson and Vergés (1952) for sheep, give rise to changing body proportions as development progresses (e.g. Hammond, 1932).

Palsson (1955) attributed these developmental changes to 'waves of growth'. A primary wave of growth was postulated from the cranium down to the facial parts of the head and caudally to the lumbar region, and a secondary wave from the distal part of the limbs and the ventral region of the trunk ending in the lumbar region. The lumbar region was described as the last part of the body to attain maximum growth rate and was, therefore, the latest maturing part of the body. Details of Palsson's conclusions have been questioned by other workers (Luitingh, 1962; Butterfield, 1964). More recent studies have sought to confirm the above pattern and illuminate any digressions within the musculature, skeletal system and the more indeterminate fat distribution.

### 2.4.2 Muscle Weight Distribution

Berg et al. (1978b) working with cattle reached similar conclusions to the earlier workers' finding that muscle growth gradients run in a centripetal direction over the limbs and in the trunk in a dorsoventral direction.

Importantly though, from a practical viewpoint, it appears that the major changes in muscle distribution in cattle are completed within the first 6 or 8 months of life (Butterfield, 1964).

A number of studies have investigated differential muscle growth patterns in serially slaughtered animals by anatomical dissection into the separate muscles, and grouping of muscles into standard muscle groups of anatomically defined regions. Two such studies with cattle (Butterfield & Berg, 1966a, b; Brännäng, 1971) and two with sheep (Lohse et al., 1971; Jury et al. 1977) have provided the basis for comparisons and discussion in recent literature. All studies have found that some individual muscles differed in their growth pattern relative to total muscle. However, different authors have failed to agree on growth classifications of individual muscles. These differences were largely attributed to differences in species, breed (Bergström, 1978; Jury et al., 1977), sex and growth range studied.

### 2.4.3 Factors Influencing Muscle Weight Distribution

The effects of species, breed, sex and growth rate have been considered in muscle weight distribution studies.

Species influences muscle weight distribution to the greatest extent. Smaller species have an increased proportion of total muscle concentrated around the spinal column, more agile species have greater

muscle development in the distal limbs, the more mobile, the greater the muscle development over the whole of the limb (Berg & Butterfield, 1976). Aggressive species have relatively larger muscles in the neck region. Domestication appears to have brought about an increase in the relative weight of the muscles of the abdominal wall (Berg & Butterfield, 1976).

Breed differences found in the muscle weight distribution of cattle when compared at similar relative maturity or similar total muscle weight have been small, (Butterfield, 1964; Kempster et al., 1976b; Truscott et al., 1976; Berg et al., 1978b; Kempster et al., 1982) and generally are not considered to be of commercial importance (Butterfield, 1964). Double-muscled cattle however exhibit greater muscling in the higher priced cuts than do normally muscled cattle (Johnson, 1981) and a more pronounced hypertrophy of the superficial muscles is noted (Bergström, 1978).

Sex differences in muscle weight distribution become apparent after puberty. In cattle the muscles of the neck and shoulder girdle region are proportionately heavier in the entire male (Berg & Butterfield, 1976) while there is a suggestion that muscles of the proximal pelvic limb, thorax and abdominal wall are proportionately heavier in cows (Bergström, 1978). Differences in muscle weight distribution between bulls and steers have also been reported (Butterfield & Berg, 1966a; Berg & Mukhoty, 1970), with a greater similarity in muscle growth pattern between steers and heifers, than steers and bulls (Berg & Butterfield, 1976).

Growth rate has generally been found not to differentially influence muscle weight distribution in cattle (Butterfield & Johnson, 1968, 1971) when comparisons are made at similar total muscle weight.

However, Murray et al. (1974) found small but significant effects of plane of nutrition on some muscles and muscle groups in cattle.

With sheep Murray and Slezacek (1976) found different growth paths to the same slaughter weight influenced the growth rate and final proportions of some muscle groups. These differences, which in general, favoured the animals in the low growth rate and interrupted growth treatments were thought to be related to their greater age and hence skeletal size.

### 2.4.4 Bone Weight Distribution

The early description by Palsson and Vergés (1952) of the growth gradients existing within the skeleton of sheep are largely supported by the more recent studies with cattle (Kempster et al., 1977; Berg et al., 1978d; Jones et al., 1978). That is, growth gradients for the bones in various joints ran centripetally from the limbs and in the posterior-anterior direction.

It has been found though that in cattle most carcass bones (or bone weights in different joints) grow at similar rates to total carcass bone over the commercial slaughter weight range (Seebeck & Tulloh, 1968; Seebeck, 1973). The leg bones have shown the greatest differences, growing proportionately more slowly than total bone.

### 2.4.5 Factors Influencing Bone Weight Distribution

There have been few studies of bone weight distribution in sheep and cattle, but existing evidence is consistent in indicating that it is a relatively inflexible characteristic.

Species influences bone weight distribution to the greatest extent in response to the functional adaptations. Small but

significant differences between cattle breeds have been found (Seebeck, 1973; Truscott et al., 1976; Kempster et al., 1977; Berg et al., 1978d; Jones et al., 1978). Generally these differences were considered commercially unimportant and they were not totally attributable to differences in relative maturity at the same total bone weight (Kempster, 1978).

Only small differences between the sexes in cattle have been recorded for bone distribution when compared on the basis of total bone weight (Bergström, 1978; Jones et al., 1978).

Different growth rates have been found to have no effect on bone weight distribution (Murray et al., 1974). This appears to be constant for all levels of nutrition.

### 2.4.6 Fat Weight Distribution

At birth most of the fat tissue is present as intermuscular and kidney fat, with an almost complete lack of subcutaneous fat. With animal growth both the intermuscular and subcutaneous depots become an increasing proportion of total fat (Berg & Butterfield, 1975). However subcutaneous fat increases at a greater proportional rate than intermuscular fat (Kempster et al., 1982).

Little information is available regarding the relative growth of subcutaneous, intermuscular and intramuscular fat in different anatomical regions of the body.

From work with sheep and pigs, Hammond (1932) proposed a growth gradient for fat deposition similar to that proposed for muscle. Recent work with cattle (Kempster et al., 1976a; Berg et al., 1978c) is in general agreement with this. That is, low growth coefficients

for the distal limb joints with increasing coefficients centripetally on the limbs and increasing further towards the rib and loin area. Highest intermuscular fat growth occurred in the thin flank joint. There was not such a clear pattern for subcutaneous fat, but high growth coefficients occurred in the rib, loin and thin flank regions (Kempster et al., 1976). Studies with sheep (Kempster, 1981) show a similar pattern to those of cattle.

The intramuscular fat depot however follows a different pattern of distribution and possibly also of differential growth from intermuscular and subcutaneous fat. Johnson et al. (1973) found in cattle that intramuscular fat content was highest in the muscles of the neck, thorax and abdominal wall and lowest in the distal muscle groups of the fore and hind limb. With increasing total dissectible fat the distribution of intramuscular fat between the different muscle groups was not affected. In cattle it appears that intramuscular fat may reach a fairly constant level of about 10% of total fat regardless of total fatness or total weight (Johnson et al., 1972).

### 2.4.7 Factors Influencing Fat Weight Distribution

While characteristic breed differences have been observed with regard to the partitioning of fat little information is available on differing breed patterns of fat distribution. In general, cattle breeds selected for beef production tend to deposit a higher proportion of their total fat subcutaneously and a lower proportion internally (perinephric and retroperitoneal regions), while the opposite holds true for dairy breeds (Kempster, 1981). With sheep differences exist between the breed extremes with the meat sire breeds

having less internal body fat than the mountain and dual purpose breeds (Kempster, 1981).

In cattle differences among sexes in fat partition between the depots have been reported to be minor when comparisons are made at equal fatness (Berg et al., 1979).

Nutrition levels have produced contradictory results regarding the fat weight distribution between depots, with high growth rates giving more subcutaneous and less intermuscular fat (Murray et al., 1974; Murray & Slezacek, 1976) or the converse (Russel et al., 1971).

## 2.5 TISSUE GROWTH PATTERNS IN DEER

Tissue growth patterns in deer are of particular interest in relation to their seasonally variable liveweight growth pattern. Given a similar prepubertal growth pattern to other species it could be assumed that relative tissue growth prepuberty would be similar. However evidence suggests that even in the first autumn of life the tissue growth pattern varies from other species. Verme and Ozoga (1980) found white-tailed deer fawns to have essentially completed their growth by mid autumn (5 months of age, mid November) in terms of the physical parameters measured such as organ weights and bone dimensions. However body fat accumulated rapidly from early autumn until early winter (mid December). The carcass weight/liveweight ratio rose steadily throughout the period, probably as a result of increased carcass fat storage. Fawns on restricted rations still managed to store fat reserves despite growing very little or even losing weight over the autumn. Verme and Ozoga (1980) concluded

that autumn lipogenesis in deer is an obligatory physiological event even with substantial food deprivation.

In mature deer gains in body weight over the summer and autumn period have also largely been attributed to increases in fat depot weights (Cook et al., 1949; Wood et al., 1962; Anderson et al., 1972). Liveweight losses over the winter period are also largely body fat (Wood et al., 1962).

In fawns body fat may be sacrificed in winter to support the gain in body protein (Thompson et al., 1973; Holter et al., 1979).

With increasing animal age the intensity of the seasonal liveweight gains and losses increases. This appears to be associated with an increasing proportion of carcass liveweight gain in summer and autumn being fat. For example, Drew (1985) found the percentage of summer/autumn carcass gain which was fat to be 14.4, 23.2 and 63.4% for yearling, 2 year old and 'aged' red deer stags respectively.

Associated with the autumn fat tissue gains the carcass water content also appears to increase in entire deer being at a maximum midrut (Cook et al., 1949). This may be accentuated in the muscles of the neck region which show enlargement at this time (Tan & Fennessy, 1981) but also appears to be a characteristic of leg and loin muscles (Cook et al., 1949).

## 2.6 MECHANISMS FOR SEASONAL LIVEWEIGHT AND TISSUE GROWTH PATTERNS IN DEER

There is considerable literature to suggest that the seasonal variation in liveweight growth in deer is mediated through changes in voluntary feed intake (VFI). That is VFI increases through summer and declines through the winter months (French et al., 1960; Norden et

al., 1970; Thompson et al., 1973; Blaxter et al., 1974; Suttie et al., 1983; Suttie et al., 1984).

This occurs in both sexes but females (Suttie, 1981) and castrates (Kay, 1979) show lower overall levels of intake and a smaller amplitude of the appetite cycle than the male.

The cyclical variation in VFI is thought to be controlled by photoperiod (McMillan et al., 1980; Simpson et al., 1984).

Accompanying the decrease in appetite over the winter is a lower fasting metabolic rate (Thompson et al., 1973), heart rate (Moen, 1978), body temperature (Holter et al., 1975) and physical activity (Moen, 1978). In addition, deer appear to markedly increase fat metabolism in the winter while having the ability to recycle urea nitrogen (McMillan et al., 1980). Recycling of urea nitrogen becomes more active as the consumption of dietary protein decreases (Robbins et al., 1974). These physiological adaptive mechanisms to maintain a favourable energy balance over periods of lowered feed intake continue even in the presence of ad lib high quality feed.

However, fawns that are heavier going into winter display a greater reduction in metabolic rate than their lighter counterparts which in turn show a less marked reduction in growth rate (Norden et al., 1970). A similar result has been obtained with mature deer where those fed a 30% reduced diet in autumn showed less appetite suppression in winter than a well fed control group (Ozoga & Verme, 1970). The above suggests a complex feedback loop to maintain homeostasis in winter (McMillan et al., 1980). For mature entire males minimum VFI has been found to correspond with peak serum testosterone levels over the rut. However information is not

available to determine whether testosterone levels control VFI or whether the two events are merely coincidental (McMillan et al., 1980). In addition, compensatory feed consumption has been noted during the declining phase of seasonal testosterone before the drop of VFI to winter levels (McMillan, 1980). It is not known to what extent autumn hypophagia operates in entire males over their first two winters.

## 2.7 MEAT QUALITY

### 2.7.1 Introduction

Meat quality covers a wide range of variables relating to the appearance, palatability, nutritive value, safety and processing characteristics of the product. In this study measurements are concentrated on two of the most consumer orientated components of meat quality: meat tenderness and colour, and the processing characteristic of water-holding capacity (WHC). The ultimate pH ($pH_u$) can be used in an attempt to explain mechanisms for differences in tenderness, colour or WHC.

In this section of the review the determinants of the above four measured variables will be discussed and the relationships which exist between them described. Most meat quality studies cited have been concerned with muscle tissue from sheep, cattle and pigs. Unless otherwise stated the major points in the following sections were reviewed by Lawrie (1979).

### 2.7.2 Meat Tenderness

The direct determinants of muscle tenderness may be defined as (1) the contractile state of the muscle proteins, (2) the amount and solubility of connective tissue and collagen components, (3) the bulk density or lubrication effects of muscle, fat and moisture, and (4) the rate and extent of post-mortem glycolysis.

Tenderness can be manipulated by the post mortem processes of conditioning, ageing, freezing and cooking. Other indirect determinants of tenderness, such as age, muscle type, nutrition and pre-mortem stress are also discussed here.

Contractile State of Muscle Proteins

The degree of muscle contraction at the time of rigor mortis is directly related to muscle tenderness on cooking. The degree of shortening of unattached muscles decreases with temperature at onset of rigor mortis, down to about 14-19 °C. Below about 14 °C there is an increasing tendency to shorten as temperature drops. This is known as cold shortening. Tenderness of cooked meat decreases as the degree of shortening increases from 20 to 40% of the initial length; thereafter, as the degree of shortening increases to 60%, tenderness once more increases.

Muscles held in a stretched state during the onset of rigor mortis are prevented from cold shortening. Shortening may therefore be very specific to muscle location because some muscles are held rigid on the carcass and all muscles are subjected to different cooling rates owing to location or the insulating effects of fat cover.

Finally, if muscles are subjected to rapid freezing pre-rigor they undergo 'thaw-rigor' on thawing (unless thawing is extremely slow). This is manifested in shortening and excessive drip loss.

Connective Tissue

The type as well as quantity of connective tissue influences meat tenderness. Individual muscles vary in their concentration of connective tissue. With increasing age the connective tissue content of the muscle generally decreases slightly but the heat insolubility of the collagen increases. However, the connective tissue component has been reported to account for less than 5% of the variability in taste panel tenderness or shear force values in beef (Cross et al., 1973).

Bulk Density or Lubrication Effects

Intramuscular fat will dilute the effects of connective tissue elements in muscle in which it is deposited. This may explain the greater tenderness reported for beef from grain-fed animals.

The intramuscular fat and moisture content of the muscle have been found to contribute to taste panel assessment of tenderness. However, the issue is complicated by the confounding effect of the degree of fatness on cold shortening and the sensory evaluation of tenderness.

Post Mortem Glycolysis

Rapid decreases in the pH of the muscle tissue post mortem causes protein denaturation and decreased solubility which may be associated with decreased tenderness. The extent of post mortem glycolysis also

has an effect on muscle tenderness. Tenderness appears to decrease as the $pH_u$ increases from 5.5 to 6.0. Above a $pH_u$ of 6.0 tenderness increases again. This enhanced tenderness at high $pH_u$ is thought to be a reflection of the greater water content and WHC of the muscle proteins and of the consequently swollen muscle fibres.

Low muscle $pH_u$ and fast rates of pH decline, which are specific to pork, are associated with the PSE condition where the muscle tissue is pale, soft and exudative. Where $pH_u$ is above 6.0 the tissue may be dark, firm and dry in appearance; known as the DFD condition. This occurs in both beef and pork.

Indirect Determinants

Tenderness has been found to be a heritable characteristic in both sheep (Purchas et al., 1969) and cattle. Increasing animal age is also generally associated with decreasing tenderness as previously mentioned. In cattle there are marked differences in tenderness between veal and mature beef, but between approximately 10 months and 3 years of age tenderness characteristics do not change appreciably. Age is considered of lesser importance with sheep and pigs where the animals are generally physiologically very young at slaughter.

In red deer slaughtered at 15 and 26 months of age, Drew (1984) found no detectable differences in tenderness of leg or loin muscles.

Of the environmental determinants of tenderness, pre-mortem stress is probably the most significant. The duration and degree of pre-mortem stress determines the muscle glycogen levels and hence the $pH_u$ and the rate of muscle post mortem glycolysis.[2]

[2]The relationship between the rate and extent of post mortem glycolysis and tenderness was discussed in the previous section.

Preslaughter stress gives rise to an accelerated rate of post mortem glycolysis, sometimes low $pH_u$ and ultimately meat of PSE character with denatured muscle proteins, lowered WHC, a looser structure which scatters light and a loss in intensity of colour of muscle pigments. The PSE condition is a common occurrence in pork.

Reduction in muscle glycogen stores prior to death, as may occur following various regimes of chronic pre-slaughter stress, results in DFD muscle. This develops when anaerobic glycolysis ceases at a high $pH_u$. DFD muscles have a high WHC and appear dark because: muscle fibres are swollen and tightly packed and so scatter less incident light than normal and the tightly packed fibres inhibit oxygen diffusion so that the layer of bright red oxymyoglobin is thin and the underlying purplish deoxygenated myoglobin predominates.

Post Mortem Determinants

These include the pre-rigor environmental temperature, muscle restraint, special treatments such as conditioning and ageing, and post-rigor treatments such as freezing and cooking.[3]

Conditioning avoids conditions that are conducive to cold shortening and thaw-rigor by holding the carcasses for about 24 hours at about 10 °C while rigor mortis takes place.

Ageing involves holding the carcasses or meat at temperatures of 4-8 °C after the onset of rigor mortis for between 12 hours and 14 days. This may occur either before or after freezing but before cooking. This process reverses the decrease in tenderness associated with the onset of rigor mortis.

[3]The first two determinants here have been discussed under Contractile state of muscle proteins.

Normal rates of freezing used in commerce have no effect on tenderness except when blast freezing occurs prior to the onset of rigor mortis, as discussed in section 5.10.1. However, Drew (1984) reported increased tenderness following the freezing of venison compared with unfrozen venison.

Cooking has the potential to decrease or increase meat tenderness depending on the temperature used and the muscle being considered. Cooking makes connective tissue more tender by converting collagen to gelatin but coagulates and tends to toughen the proteins of the myofibril. Prolonged cooking times and relatively low temperatures are necessary for the softening of the collagen.

### 2.7.3 Colour

The colour of muscle tissue is determined by the quantity of the pigment myoglobin present, its chemical state and on the chemical and physical condition of other components in the meat. Generally a high level of muscular activity increases the amount of myoglobin hence the colour intensity.

The colour of fresh meat is determined mainly by the relative proportions of the three meat pigments: purple reduced myoglobin (Mb), red oxymyoglobin ($MbO_2$) and brown metmyoglobin (Met Mb). Oxymyoglobin is formed by a reversible combination of Mb with molecular oxygen from the atmosphere in the top 2 mm layer of the cut meat surface. When the muscle surface is exposed to the air for several days a non-reversible oxidation of $MbO_2$ to the highly stable Met Mb can occur.

The physical condition of the muscle (i.e. PSE or DFD) affects colour as discussed in the section on Indirect Determinants.

### 2.7.4 Water-Holding Capacity (WHC)

The WHC of muscle is determined by the extent to which water is held within the micro-structure of the tissue (Hamm, 1975). Actual exudation also depends on the extent to which water is permitted access to the exterior.

Hence the WHC of the muscle has a direct effect on the shrinkage and weight loss of meat during storage. Weep is discriminated against by the consumer and in the meat processing industry the correct water to protein ratio is important for palatability and yield considerations.

Conditions conducive to a rapid rate of PM glycolysis or low $pH_u$ also decrease the WHC of muscle tissue. This is largely attributed to denaturation of the muscle proteins and contraction of the actomyosin formed, which expresses the fluid dissociated from the proteins. The lower the $pH_u$ (down to about 5.5) the higher the drop in WHC. Ageing has been found to increase muscle WHC and freezing can increase the potential for water loss on thawing if the rate of freezing is slow.

Finally, WHC has been found to increase with increasing animal age in cattle, but not so in pigs.

### 2.7.5 Ultimate pH

This is the final pH attained by the muscle tissue post mortem and is determined by the concentration of lactic acid in the tissue. The pH decline stops because of lack of glycogen, inactivation of the glycolytic enzymes or because the glycogen is insensitive or

inaccessible to attack. Generally $pH_u$ is about 5.5 but it varies with species and muscle type and decreases with increasing animal age.

The $pH_u$ may be the most telling variable of the events occurring immediately pre-slaughter and post mortem. In cattle and pigs pre-slaughter stress may deplete muscle glycogen reserves, thus increasing $pH_u$. At pH values greater than about 6.0 the DFD condition, where the meat is dark, firm and dry in appearance, may prevail. In pigs very low $pH_u$ values may result in PSE pork, where the meat appears pale, soft and exudative. However rapid rates of pH fall to normal meat pH values may also result in the PSE condition. In this case, the $pH_u$ would not be indicative of this meat condition.

The $pH_u$ is influenced very little by other post-slaughter processes. It may increase by a small amount on ageing but is unaffected by freezing.

# Chapter 3

# EXPERIMENTAL

## 3.1 EXPERIMENTAL DESIGN

Three groups of 8 entire male fallow deer (Dama dama) were slaughtered at approximately 13 months (mid January), 17 months (late May) and 25 months of age (mid January) during 1982.

The deer allocated to the 13- and 17-month-old groups and the 25-month-old group were selected at random from 26 yearling and 23 two-year-old animals respectively raised on pasture on a commercial deer farm near Te Puke, Bay of Plenty, New Zealand.

The establishment breeding stock for this farm were trapped from feral fallow deer populations in the Wanganui region prior to 1979.

## 3.2 SLAUGHTER PROCEDURES

Slaughter procedures differed between the treatment groups in that the 13- and 25-month-old deer (groups M13 and M25 respectively) were processed through a slaughter house while the 17-month-old animals (group M17) were shot in the paddock and dressed on the farm. These procedures are described below.

### 3.2.1 Slaughter House Procedure (January)

The 13- and 25-month-old deer were transported 300 km to a licensed Deer Slaughter Premises at South Kaipara Head 4 days prior to slaughter. The animals were yarded 4 hours before slaughter and penned in small groups in a darkened holding area to await pre-mortem veterinary inspection. Stunning was performed using a captive bolt pistol. Prior to bleeding any antler or velvet present was removed from the head below the pedicle.

A period of 3 hours elapsed between the slaughter of the first and last animals. Dressing followed common slaughter house procedure. Approximately 30 minutes after dressing the intact carcasses were chilled (~4 °C) for 18 hours, until jointing.

The commercial cuts (Fig. 3.1) from the left hand side of the carcass plus any associated trim were weighed following jointing and boning out. The untrimmed cuts from the right hand side of the carcass were weighed, blast frozen and then held at below freezing point (-18 °C) until dissection approximately 5 months later.

### 3.2.2 On-Farm Slaughter Procedure (May)

The 17-month-old deer were slaughtered during May, in the middle of the rutting period (mating season) of the fallow deer in New Zealand. During the rut male fallow deer exhibit aggressive behaviour towards other deer, especially when placed under the stress of confinement. This behaviour can result in animal injury and death. For this reason the animals were shot in the paddock on the farm.

Immediately after being shot each animal was bled and hung (skin on) to await dressing by normal slaughterhouse procedures. Slaughter took place over 2.5 hours and dressing commenced 1 hour later, being completed in 3 hours. The dressed carcasses were hung intact for 16 hours at air temperatures between approximately 4 and 12 °C. The untrimmed commercial cuts were weighed after jointing. The cuts from the right side were placed in plastic bags and packed in ice for 7 hours (during transport) before freezing (-18 °C) at Massey University Animal Science Department meat laboratory. The dissection of cuts commenced approximately 2 months later.

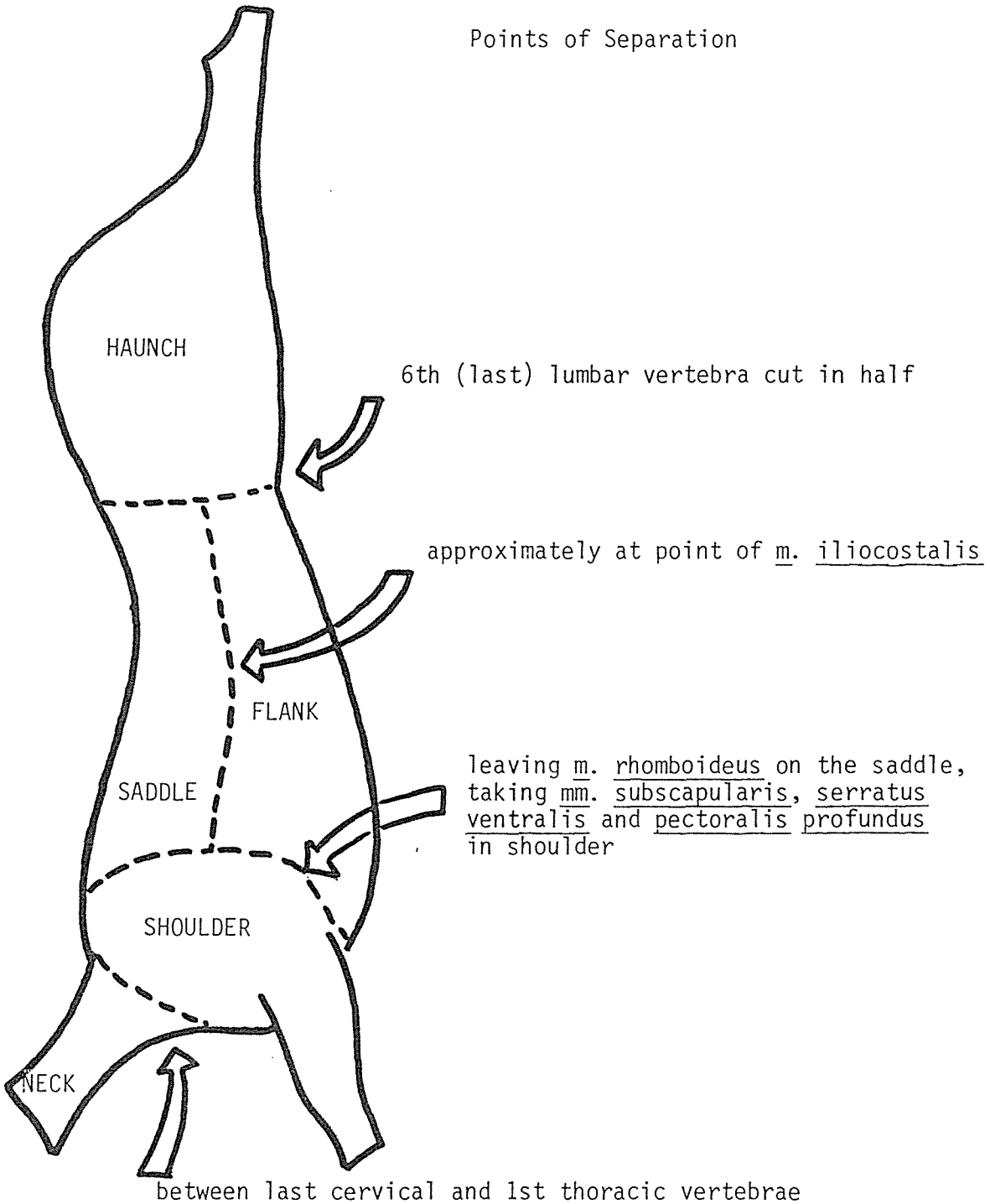


Figure 3.1. Dissected cuts in carcass separated down mid-line.

### 3.2.3 Body Components Measured at Slaughter

An estimate of animal liveweight was obtained by weighing the intact carcass prior to bleeding. The non-carcass components (described in Table 3.1) were measured during or within 3 hours of dressing.

Hot carcass weight (immediately following dressing) and cold carcass weight (chilled 18 hours) were recorded.

Linear measurements (Table 3.2) were taken on the chilled 13- and 25-month-old carcasses prior to jointing. Such measurements on the 17-month-old group were discarded because of inconsistencies in the experimental technique.

For both slaughter dates the dressing procedure and separation of non-carcass components prior to measurement was standardised as far as possible. The same slaughterman was employed on both occasions. However, it was observed that discrepancies did occur and these are noted where appropriate.

## 3.3 DISSECTION PROCEDURE

Each of the 5 commercial cuts taken from the right hand side of the carcass was thawed (10 hours at room temperature), weighed to the nearest gram, and then separated by knife into the components of fat, muscle, bone and scrap.

### 3.3.1 Subcutaneous Fat

Distinct separation between subcutaneous and intermuscular fat was difficult in certain regions on the flap and shoulder cuts. However, guideline boundaries established in early dissections were adhered to.

**Table 3.1.** Description of non-carcass components

| Component Measured[1] | Description |
|---|---|
| Blood | Collected at slaughter from severed carotid arteries, body suspended by hind limbs to facilitate drainage. |
| Hide | Skin and hair covering from whole body excluding that covering head and limbs distal to carpo-metacarpal and tarso-metatarsal joints, including tail. |
| Head[2] | Removed from body at atlanto-occipital articulation, pedicles removed at skull level. |
| Legs | Separated distal to the carpals and tarsals. |
| Pizzle[2] | Comprised of testicles, epididymi, scrotum, vas deferens, accessory glands, penis and penis sheath. |
| Heart | Emptied of blood, arteries and venae removed at level of auricles. |
| Lungs[2] | As presented for inspection, including some tracheal tissue. |
| Liver | Gall bladder removed. |
| Gut | Included emptied rumen, reticulum, omasum and abomasum, spleen, intestines, omental and mesenteric fat. |
| Metacarpal | Weight measured cleaned of fat, tendons and ligaments. Length (mm) and circumference (mm) after Palsson (1939). |

[1]Measurement by weight unless otherwise stated
[2]Data from groups M13 and M25 only

**Table 3.2** Description of carcass linear measurements

| Measurement | Description |
|---|---|
| LB | Carcass length from gambrel to point of shoulder. |
| T | Length of tibia and tarsus on carcass. |
| F | Length of inside hind leg from gambrel to pelvis bone. |
| G | Width of gigots. |
| WF | Maximum width of forequarter. |
| WTH | Minimum width of forequarter behind scapulae. |
| N | Neck circumference at point where mm. trapezius and brachiocephalicus meet on top of neck. |

### 3.3.2 Intermuscular Fat

This included all separable fatty tissue other than that designated as subcutaneous or kidney fat. It also included all the fatty tissue found on the neck cut.

### 3.3.3 Kidney Fat

Although most of the kidney fat had been removed at jointing, some remained on the saddle and flap cuts to be removed at dissection.

### 3.3.4 Muscle

The thicker tendons and aponeuroses were removed from the muscles but epimysium was included with the muscle. Certain muscles (Table 3.3) were removed intact for individual weighing and use in quality assessment studies.

### 3.3.5 Bone

Bones were cleaned of muscle, tendon and fatty tissue. Cartilage was left on the bones. Inaccurate splitting or separation of the neck, saddle, hind and flap cuts at jointing may have influenced the weight of total bone in these cuts. Where necessary, correction for inaccurate splitting of soft tissue was made by removal and weighing of the tissue. Weights and linear measurements of a number of bones (Table 3.3) were recorded.

**Table 3.3.** Individually weighed muscles, bones, or combinations of bones

| | Cut Location |
|---|---|
| Muscles | |
| M. splenius | Neck |
| M. semispinalis | Neck |
| M. semitendinosus | Haunch |
| M. semimembranosus | Haunch |
| M. gluteobiceps | Haunch |
| M. quadriceps femoris | Haunch |
| Bones | |
| Radius and ulna | Shoulder |
| Humerus | Shoulder |
| Scapula | Shoulder |
| Femur[1] | Haunch |
| Tibia and tarsus | Haunch |

[1]Length also measured

### 3.3.6 Scrap

This component included tarsals, tendons, aponeuroses, lymph nodes and glandular tissue.

### 3.3.7 Measurements Made During Dissection

Tissue components were weighed, wrapped in plastic, and then chilled when approximately 1 kg was obtained, in order to minimise loss of water.

A tracing of the m. longissimus cross section was taken on the cut surface between the 12th and 13th rib. From this the area (EMA) of the muscle was determined. Also at this point the thickness of backfat over the deepest part of the m. longissimus (C) was recorded.

## 3.4 WATER, LIPID, ASH AND PROTEIN DETERMINATION

### 2.4.1 Tissue Preparation

Each of the 4 main tissue groups (subcutaneous fat, intermuscular fat, muscle, bone) from all cuts was combined and minced for each carcass. Details of this process are described in Table 3.4. Also, an internal tissue sample from each of 4 muscles (mm. longissimus, gluteobiceps, semimembranosus, semispinalis) was individually minced using scissors. The minced tissues were thoroughly mixed and 2 samples of between 10 and 13 g were taken. These samples were then individually wrapped in pre-weighed aluminium foil and refrozen.

**Table 3.4.** Tissue mincing procedures

| Tissue | Preparation | Mincing Details |
|---|---|---|
| Subcutaneous fat<br><br>Intermuscular fat | - | (a) If sample >1000 g - twice through 6 mm diameter plate.<br>(b) If sample <1000 g - once through each of 8 mm and 4 mm diameter plates. |
| Muscle | Larger muscles and those with thick connective sheaths cut into pieces. | Twice through 6 mm plate. |
| Bone | Thicker bones shattered. | Once through each of 15 mm, 10 mm and 6 mm diameter plates. |

### 3.4.2 Water Determination

The frozen tissue samples were freeze-dried for 48 hours, oven dried (80 °C) for 24 hours, cooled in a desiccator and then weighed. This is a similar technique to that used by Morris and Moir (1964), except freeze-drying and oven drying times were increased to compensate for the lower oven drying temperature used. Lower oven temperatures were used to prevent total liquefaction of the fat tissue samples.

### 3.4.3 Lipid Determination

The dried tissue samples were extracted in a Soxhlet apparatus with petroleum ether (40-60 °C Boiling point), using a condensing rate that provided a continuous flow of solvent, for 9 hours (A.O.A.C., 1980). The fat extract weighed in the dry flask following extraction was termed the lipid component.

### 3.4.4 Ash Determination

The dried fat-free samples were ashed in tared crucibles at 550 °C for 10 hours (Morris and Moir, 1964). They were cooled in a desiccator and then weighed.

### 3.4.5 Protein Determination

The protein component was estimated as the difference between the sum of the water, lipid and ash components and the initial weight of the sample.

## 3.5 MEAT QUALITY ASSESSMENT

### 3.5.1 General

Measurements of aspects of meat quality made, on a major leg muscle (m. semimembranosus) and the main back muscle (m. longissimus) included Warner-Bratzler shear values on cooked samples, pH, water-holding capacity and colour. Observations on the presence of bruising and ecchymosis (blood splash) were also recorded. After being dissected from their respective cuts and weighed, the 2 muscles were kept chilled (0-3 °C) in plastic bags for not more than 12 hours prior to the above measurements being made.

### 3.5.2 Meat Tenderness Measurement

Three 25 mm-thick steaks were cut from the m. longissimus (13th thoracic, 1st lumbar rib region) (LD) and two were cut from the m. semimembranosus (SM) at the time of muscle separation. The steaks were stored at chiller temperatures in plastic bags until cooked by immersing the bags in a water bath at 70 °C for 90 minutes (Purchas, 1972). After cooling, 3 and 4 cores (13 mm x 13 mm cross section)

were cut parallel to the muscle fibres for each LD and SM steak respectively. Each core was then sheared perpendicular to the fibres in 2 places, with a Warner-Bratzler shear device. This machine measured the maximum force required to cut across the muscle fibres (Pearson, 1963).

### 3.5.3 Muscle pH Measurement

The pH of duplicate muscle samples were measured approximately 12 hours post-thawing using the following procedure.

- A 1-2 g sample of freshly cut muscle tissue was dropped into 10 ml of chilled 5 mM iodoacetate and chopped finely with scissors.
- The mixture was homogenised to a fine slurry using a glass homogeniser.
- The pH meter (Radiometer pH Meter 29) was standardised using 2 standard buffer solutions (pH 4.0 and 7.0).
- The pH of the slurry was read. The electrode was washed well with distilled water between measurements and frequently with acetone as well.

### 3.5.4 Water-Holding Capacity Measurement

The water-holding capacity (WHC) of triplicate muscle samples was measured approximately 12 hours post-thawing using the following procedure (Grau and Hamm, 1957).

- The 200-300 mg freshly cut muscle sample was weighed on a tared filter paper (Whatman 1 11.0 cm Qualitative, stored in desiccator over saturated KCl).

- After covering with a second filter paper, the sample was placed between 2 Plexiglass plates and pressed by tightening screws to hand pressure. Pressure was maintained for 3 minutes.
- At removal, the inside circle defining the area to which the meat was pressed, was outlined.
- The areas of expressed juice and meat film were measured using an area integrating package on an Apple II microcomputer.

The difference between the area of the inner and outer circles was taken as a measure of "free" or "loose" water (Hamm, 1975), an inverse measure of the WHC of the meat.

Two methods were used to express this:

1. $\frac{\text{total area - meat film area (cm}^2\text{)}}{\text{weight of sample (g)}}$ = expressible juice (cm$^2$/g)

2. $\frac{\text{total area - meat film area (cm}^2\text{)}}{\text{inner meat film area (cm}^2\text{)}}$ = expressible juice index

### 3.5.5 Muscle Colour Measurement

A sample cut from the m. longissimus and m. semimembranosus (1 cm thickness, 12 hours post-thawing), free from connective and fatty tissue, was exposed to the atmosphere at chiller temperatures for 1 hour before measurement.

Muscle colour was measured using a Spectrophotometer (Bausch and Lamb Spectronic 20) with an integrating sphere reflectance attachment. Reflectance readings were made at wavelengths of 580 and 630 nm. The instrument was zeroed frequently during measurement using the reference standards supplied by the manufacturer.

The difference, R630-R580, was calculated as a measure of meat colour (Strange et al., 1974). An increase in the difference between R630 and R580 is associated with more red oxymyoglobin relative to brown metmyoglobin. This difference has been shown to have a high linear correlation coefficient (-0.86) with hedonic methods for beef muscle colour evaluation (Strange et al., 1974).

### 3.6 DATA PRESENTATION AND STATISTICAL METHODS

The relative growth of the carcass and body components was examined using the allometric equation of Huxley (1932) (see Section 2.3.1). Allometric growth coefficients or b-values were calculated for the pooled age group data. These were tested for significant differences from 1.0 by use of tests of significance for regression coefficients outlined by Steele and Torrie (1960). The coefficients were classed according to the system of Butterfield and Berg (1966a) whereby a coefficient significantly greater than 1.0 ($P<0.05$) represented a high growth impetus (H), less than 1.0 a low growth impetus (L) and not significantly different from 1.0 an average growth impetus (A).

However, one problem with such a classification system is that in 'small scale' experiments, such as the present study, the small number of animals can influence the growth impetus classification greatly where large standard errors occur. Therefore consideration was also given to the relative magnitudes of the allometric growth coefficients in the discussion.

Allometric growth coefficients were used to relate linear measurements (e.g. carcass length) to gravimetric measurements (e.g.

carcass weight). It was recognised that in the above relationships low b-values could be expected because the actual relationship between the x and y variates should be $x \simeq f(\sqrt[3]{y})$. Also, the metacarpal weight was related to total carcass bone weight using the allometric growth equation despite the metacarpal not being part of the total bone weight.

The effects of age and carcass weight could not be separated in this study as the two variables were highly correlated. Only a small overlap in carcass weights existed between groups M13 and M17. Within age groups, analyses were not performed because of the low numbers of animals per group (8) and the relatively small range in carcass weight for each group. The linear and logarithmic regressions were therefore performed on the pooled group data.

Tables of age group means with standard errors ($SE = \sqrt{\hat{\sigma}^2/r}$) and standard errors of difference ($SED = \sqrt{2\hat{\sigma}^2/r}$), where r equals number of replicates, are presented for all data. For comparisons between pairs of means the least significant difference (LSD) can be calculated by

$$LSD\ (0.05) = t_{0.05} \times SED$$

and $$LSD\ (0.01) = t_{0.01} \times SED.$$

where in this study the error d.f., f = 21 and $t_{(0.05,\ 21)} = 2.080$; $t_{(0.01,\ 21)} = 2.831$ (Steel and Torrie, 1960).

If the difference between two means is greater than the LSD value then these two means differ significantly at the respective significance level.

# Chapter 4

# RESULTS

## 4.1 LIVEWEIGHT, CARCASS WEIGHT AND CARCASS DIMENSIONS

### 4.1.1 Relationships Between Liveweight and Carcass Weight

The mean unfasted liveweight, hot and cold carcass weights and dressing-out percentages for the three age groups are given in Table 4.1. All calculations involving carcass weight have been based on the cold carcass weight (kidneys and kidney fat intact). Cold carcass weight showed a close linear relationship with unfasted liveweight across the three age groups (Fig. 4.1). The allometric growth coefficient (AGC) for this relationship was calculated to be 1.11 ($SE_b$ = 0.04, $r^2$ = 0.97) and the carcass was classed as having a high growth impetus relative to liveweight ($P<0.05$).

Predicted dressing-out percentage increased by 5.5% over the liveweight range studied. It was 58.6% at 41 kg and 61.8% at 66 kg.

Carcass weight loss on cooling was 2.5% (SE = 0.09), 0.5% (SE = 0.52) and 2.2% (SE = 0.13) for groups M13, M17 and M25 respectively.

Dissection losses, calculated over the period from the freezing of the side cuts to weighing of dissected tissues, were 0.99, 0.97 and 1.02% (mean = 0.99%, SE = 0.03) for groups M13, M17 and M25 respectively.

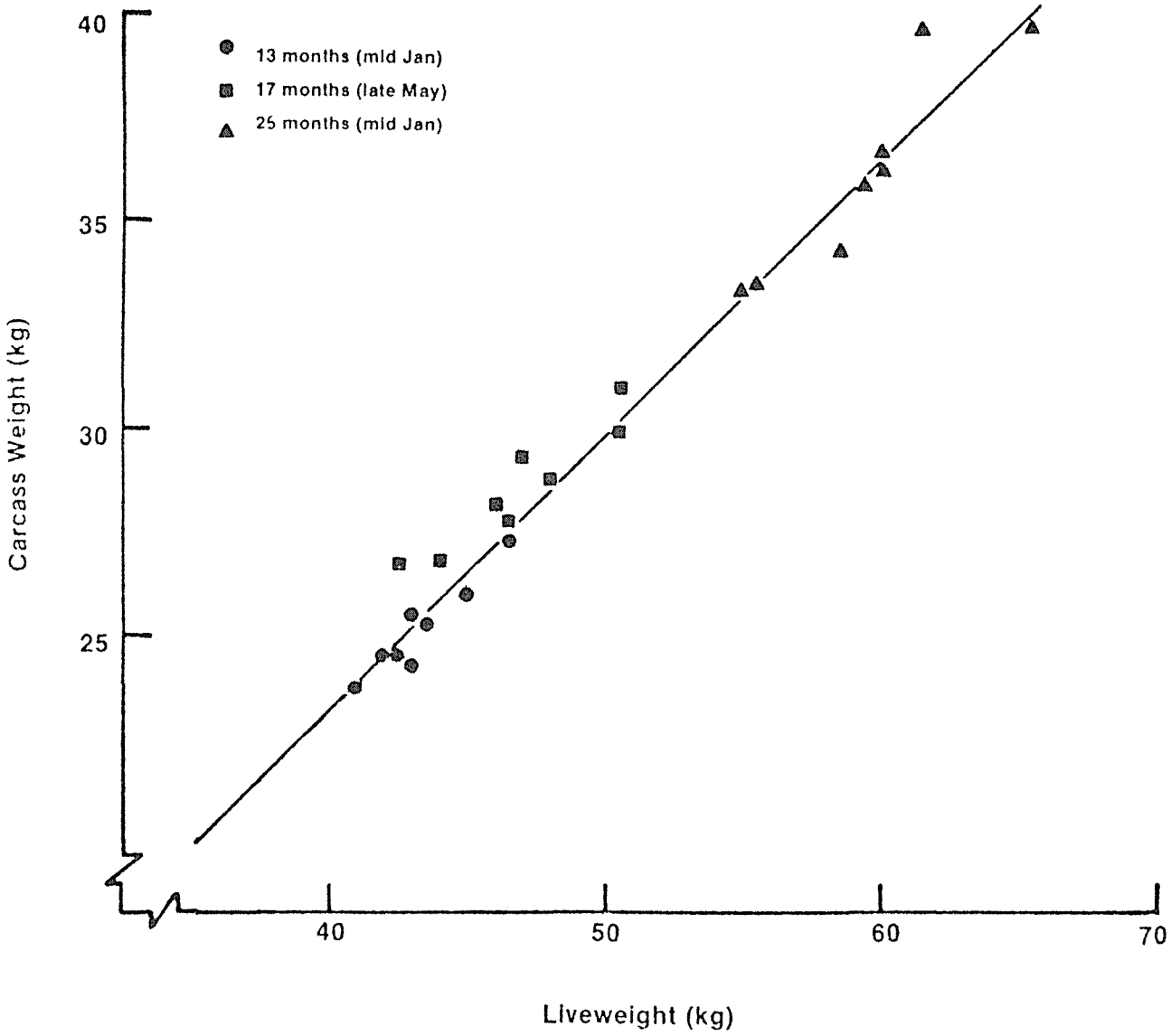


Figure 4.1. The relationship between carcass weight (y) and liveweight (x) for 24 male fallow deer ($y = 0.664x - 3.29$, $r^2 = 0.97$).

**Table 4.1.** Animal age (months), liveweight (kg), carcass weight (kg) and dressing-out percentage for the three age groups. [Mean value (SE)]

| Group | Age[1] | Liveweight[2] | Carcass weight | | Dressing-out percentage |
|---|---|---|---|---|---|
| | | | Hot | Cold[3] | |
| M13 | 13 | 43.5 (0.6) | 25.6 (0.4) | 25.0 (0.4) | 58 (0.3) |
| M17 | 17 | 47.0 (1.0) | 28.6 (0.6) | 28.5 (0.5) | 61 (0.4) |
| M25 | 25 | 59.5 (1.2) | 36.9 (0.9) | 36.1 (0.9) | 61 (0.7) |
| Significance Level[4] | | *** | *** | *** | *** |
| SED[5] | | 1.3 | 1.0 | 0.9 | 0.7 |

[1]Mean age (range ± 15 days)
[2]As estimated by dead weight prior to exanguination
[3]Measured 21 hours after hot carcass weight
[4]*(P<0.05), **(P<0.01), ***(P<0.001)
[5]Standard error of difference (see section 3.6)

### 4.1.2 Carcass Linear Measurements

The carcass linear measurements recorded for groups M13 and M25 are presented in Table 4.2. All dimensions increased significantly between M13 and M25, but relative to carcass weight carcass linear measurements had low growth impetus (Table 4.3).

With carcass length instead of carcass weight as the independent variate, high and average relative growth impetus were shown for WF, WTH and N and T, F and G respectively.

**Table 4.2.** Carcass linear measurements (in mm) for groups M13 and M25. [Mean values (SE)]

| Linear Measurement[1] | Group M13 | Group M25 | Significance Level[2] |
|---|---|---|---|
| LB | 1148 (8) | 1253 (5) | *** |
| T | 243 (2) | 264 (2) | *** |
| F | 397 (3) | 430 (2) | *** |
| WF | 194 (2) | 218 (3) | *** |
| WTH | 164 (1) | 190 (4) | *** |
| G | 256 (2) | 286 (3) | *** |
| N | 81 (1) | 99 (2) | *** |

[1]Described in Table 3.2
[2]* ($P<0.05$), ** ($P<0.01$), *** ($P<0.001$)

**Table 4.3.** Allometric growth coefficients and the growth impetus of carcass linear measurements relative to carcass weight and carcass length for animals in groups M13 and M25.

| Linear Measurement[1] | Allometric Growth Coefficient[2] b | $SE_b$ | $r^2$ | Relative growth impetus[3] |
|---|---|---|---|---|
| Carcass weight as independent variate | | | | |
| LB | 0.24*** | 0.02 | 0.85 | L |
| T | 0.22*** | 0.02 | 0.92 | L |
| F | 0.22*** | 0.02 | 0.92 | L |
| WF | 0.33*** | 0.03 | 0.88 | L |
| WTH | 0.40*** | 0.05 | 0.83 | L |
| G | 0.31*** | 0.03 | 0.91 | L |
| N | 0.55*** | 0.06 | 0.88 | L |
| Carcass length (LB) as independent variate | | | | |
| T | 0.93 | 0.06 | 0.93 | A |
| F | 0.90 | 0.05 | 0.96 | A |
| WF | 1.33* | 0.16 | 0.84 | H |
| WTH | 1.58* | 0.24 | 0.75 | H |
| G | 1.22 | 0.15 | 0.83 | A |
| N | 2.24*** | 0.25 | 0.86 | H |

[1]Described in Table 3.2

[2]Slope term (b) and its standard error ($SE_b$) for the allometric regression with significance levels for difference of b from 1.0; * (P<0.05), ** (P<0.01), *** (P<0.001)

[3]H = high (significantly > 1.0), A = average (not significantly different from 1.0), L = low (significantly less than 1.0), see section 3.6 for further detail

## 4.2 CARCASS COMPOSITION

### 4.2.1 Carcass Dissectible Components

Mean weights of the main tissue components of the carcass, expressed as percentages of carcass weight, are given for the three age groups in Table 4.4

From Table 4.4 it can be seen that the general trend with increasing age group was for decreases in the percentages of bone, muscle, and kidney organ, and increases in the percentages of subcutaneous, intermuscular and kidney fats. However, apart from the percentage of subcutaneous fat the differences were not statistically significant between groups M17 and M25.

**Table 4.4.** The main carcass tissue components for the three age groups expressed as percentages of carcass weight. [Mean values (SE)]

| Group | Bone | Muscle | Fat | | | Kidney |
|---|---|---|---|---|---|---|
| | | | Subcut. | Intermuscular | Kidney | |
| M13 | 14.3 (0.03) | 74.3 (0.78) | 2.6 (0.21) | 4.6 (0.32) | 0.63 (0.06) | 0.48 (0.02) |
| M17 | 13.0 (0.14) | 71.5 (0.50) | 3.3 (0.18) | 5.4 (0.21) | 0.72 (0.05) | 0.45 (0.03) |
| M25 | 12.3 (0.28) | 70.1 (0.67) | 5.5 (0.42) | 5.9 (0.18) | 0.87 (0.11) | 0.43 (0.01) |
| Significance[1] level | *** | *** | *** | ** | NS | NS |
| SED[2] | 0.36 | 0.91 | 0.42 | 0.33 | 0.11 | 0.30 |

1, 2 See footnotes 4 and 5, Table 4.1

Linear regression coefficients and allometric growth coefficients between carcass weight and weights of the main carcass tissues are given in Table 4.5. Close linear relationships occurred between carcass weight and bone, muscle, subcutaneous fat and intermuscular fat weights. Greater variation surrounded relationships of kidney and kidney fat weights, with carcass weight.

From the allometric growth coefficients it appeared that bone and muscle had low growth impetuses relative to carcass weight, while the subcutaneous and intermuscular fat depots were each classified as having high relative growth impetus.

Kidney fat and kidney organs, with growth coefficients not significantly different from 1.0, each had an average growth impetus relative to carcass weight.

The growth patterns of the carcass muscle and bone were also examined relative to the weight of muscle plus bone in the carcass as the independent variate. Results of such analyses (Table 4.6) show that the allometric growth coefficients for bone and muscle relative to muscle plus bone shift closer to one than when analysed relative to carcass weight. The growth impetus of muscle also changed from low to high. These allometric growth coefficients suggest that the muscle to bone ratio (M:B) increased with increasing carcass weight. The relationship between M:B(y) and carcass weight (x) is given by the linear regression equation 4.1.

| | SEa | SEb | $r^2$ | |
|---|---|---|---|---|
| $y = 4.23 + 0.042x$ | 0.29 | 0.01 | 0.46 | (4.1) |

**Table 4.5.** Linear regression analyses and allometric growth coefficients for the main carcass tissue components (g) relative to carcass weight (kg).

| Carcass Component | Linear Regression[1] | | | | | Allometric Growth coefficient[2] | | | Relative growth impetus[3] |
|---|---|---|---|---|---|---|---|---|---|
| | a | $SE_a$ | b | $SE_b$ | $r^2$ | b | $SE_b$ | $r^2$ | |
| Bone | 1524 | 261 | 79.7 | 8.6 | 0.80 | 0.62*** | 0.07 | 0.79 | L |
| Muscle | 3311 | 652 | 606 | 22 | 0.97 | 0.85*** | 0.03 | 0.97 | L |
| Subcutaneous fat | -2211 | 400 | 114 | 13 | 0.77 | 2.85*** | 0.03 | 0.80 | H |
| Intermuscular fat | - 839 | 239 | 81.7 | 7.9 | 0.83 | 1.61** | 0.19 | 0.75 | H |
| Kidney fat | - 168 | 95 | 13.2 | 3.1 | 0.45 | 1.64 | 0.37 | 0.48 | A |
| Kidneys | 28.3 | 22.0 | 3.52 | 0.73 | 0.52 | 0.78 | 0.17 | 0.48 | A |

[1]Intercept (a) and slope (b) terms and their respective standard errors ($SE_a$, $SE_b$) for the linear regression

[2]Slope term (b) and its standard error ($SE_b$) for the allometric regression with significance levels for differences of b from 1.0. *(P<0.05), **(P<0.01), ***(P<0.001)

[3]H = high (significantly > 1.0), A = average (not significantly different from 1.0), L = low (significantly < 1.0). See section 3.6 for further detail

**Table 4.6.** Linear regression analyses and allometric growth coefficients for the weight of carcass bone and muscle tissue relative to the weight of carcass bone plus muscle.[1]

| Carcass Component | Linear Regression | | | | | Allometric Growth coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | a | $SE_a$ | b | $SE_b$ | $r^2$ | b | $SE_b$ | $r^2$ | |
| Bone | 851 | 234 | 0.121 | 0.009 | 0.89 | 0.79** | 0.06 | 0.89 | L |
| Muscle | 851 | 234 | 0.879 | 0.009 | 0.99 | 1.04** | 0.01 | 0.99 | H |

[1]See footnotes Table 4.5

### 4.2.2 Carcass Chemical Components

The weights of the chemical components of the carcass, expressed as percentages of side weight (without kidneys or kidney fat), are given for the three age groups in Table 4.7). The general trend was for a decrease in the percentage of water and an increase in the percentage lipid with increasing age group. The percentage ash was constant across all groups, while the percentage protein was greater in group M17 than in both groups M13 and M25. The protein percentage was also greater in group M13 compared to group M25. Development of the carcass chemical components relative to carcass weight is described by the linear regressions in Table 4.8. Based on the allometric growth coefficients (Table 4.8) water and protein had low, lipid had a high, and ash an average growth impetus relative to carcass weight.

**Table 4.7.** Carcass chemical components for the three age groups expressed as a percentage of side tissue weight. [Mean values (SE)]

| Chemical Component | Group | | | Significance of difference[2] | SED[3] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Water | 66.8 (0.4) | 65.1 (0.2) | 63.6 (0.5) | *** | 0.54 |
| Lipid | 6.2 (0.4) | 7.5 (0.3) | 10.1 (0.6) | *** | 0.63 |
| Ash | 5.7 (0.1) | 5.7 (0.1) | 5.7 (0.1) | NS | 0.12 |
| Protein[1] | 21.6 (0.1) | 22.0 (0.1) | 21.0 (0.1) | *** | 0.15 |

[1]Calculated by difference
[2,3] See footnotes 4 and 5, Table 4.1

**Table 4.8.** Linear regression analyses and allometric growth coefficients of the carcass chemical components relative to side weight (g).[1]

| Chemical Component | Linear Regression | | | | | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | a | $SE_a$ | b | $SE_b$ | $r^2$ | b | $SE_b$ | $r^2$ | |
| Water | 1173 | 235 | 0.547 | 0.016 | 0.98 | 0.87*** | 0.03 | 0.98 | L |
| Lipid | -1461 | 269 | 0.180 | 0.018 | 0.82 | 2.22*** | 0.24 | 0.80 | H |
| Ash | - 184 | 42.4 | 0.056 | 0.003 | 0.95 | 1.03 | 0.06 | 0.94 | A |
| Protein | 342 | 81 | 0.184 | 0.005 | 0.98 | 0.89** | 0.03 | 0.97 | L |

[1]See footnotes Table 4.5

### 4.2.3 Commercial Carcass Cuts

The weight of untrimmed commercial cuts in one side of the carcass, expressed as percentages of side weight, are shown in Table 4.9. As the separation of saddle and flank cuts was not on the basis of a defineable anatomical feature analyses for the saddle plus flank weight as well as the separate weights are presented in this and later sections. The age group cut percentages, while differing significantly in most cases, did not reveal any simple linear growth trend with increasing side weight. However from the growth coefficients (Table 4.10) the proportion of shoulder and haunch decreased, flank increased and neck and saddle remained about constant over the range in side weights studied.

**Table 4.9.** Weight of side cuts expressed as a percentage of side weight for the three groups. [Mean values (SE)]

| Side cut | Group | | | Significance of difference[2] | SED[3] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Neck[1] | 11.2 (0.3) | 13.1 (0.3) | 11.6 (0.3) | *** | 0.43 |
| Shoulder | 18.0 (0.1) | 18.1 (0.3) | 17.2 (0.1) | ** | 0.28 |
| Saddle[1] | 15.2 (0.5) | 15.8 (0.3) | 15.6 (0.3) | NS | 0.52 |
| Flank | 15.0 (0.4) | 14.5 (0.3) | 16.7 (0.3) | *** | 0.45 |
| Saddle + Flank | 30.2 (0.3) | 30.3 (0.2) | 32.3 (0.4) | *** | 0.43 |
| Haunch | 40.6 (0.2) | 38.5 (0.2) | 39.0 (0.3) | *** | 0.29 |

[1]These represent half the corresponding commercial cuts
[2,3] See footnotes 4 and 5, Table 4.1

**Table 4.10.** Allometric growth coefficients of the side cuts relative to side weight.[1]

| Side cut | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|
| | b | $SE_b$ | $r^2$ | |
| Neck | 1.02 | 0.13 | 0.73 | A |
| Shoulder | 0.87** | 0.04 | 0.95 | L |
| Saddle | 1.04 | 0.09 | 0.86 | A |
| Flank | 1.33** | 0.09 | 0.91 | H |
| Saddle + Flank | 1.18*** | 0.04 | 0.98 | H |
| Haunch | 0.91** | 0.03 | 0.97 | L |

[1]See footnotes 2 and 3, Table 4.5

### 4.3 NON-CARCASS BODY COMPONENTS

The weights of the non-carcass body components for the three groups (Table 4.11) are expressed as a percentage of empty body weight (EBW) in Table 4.12. For group M17 the results were omitted because component preparation was not standard.

The weights of all the non-carcass components increased with increasing EBW, however the differences were not statistically significant between group M13 and M17 for the legs and heart or between group M17 and M25 for the gut.

As a percentage of EBW, legs, lungs and head decreased with increasing EBW. The percentage of blood, hide, heart and pizzle did not change with increasing EBW. The pattern for the liver, gut and total non-carcass components was not consistent. These differences are generally consistent with the differences in the allometric growth

coefficients (Table 4.13). With the legs, liver, lungs, head, gut and total non-carcass components each having a low growth impetus while the blood, hide, heart and pizzle each had an average growth impetus relative to EBW.

**Table 4.11.** The weight of non-carcass body components (g) for the three age groups. [Mean values (SE)]

| Non-carcass component | Group | | | Significance of difference[1] | SED[2] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Blood | 1743 (116) | - | 2339 (135) | ** | 178 |
| Hide | 2556 (65) | 2809 (77) | 3621 (60) | *** | 96 |
| Legs | 1175 (15) | 1195 (23) | 1378 (22) | *** | 29 |
| Liver | 749 (8) | 825 (21) | 973 (25) | *** | 28 |
| Heart | 369 (5) | 386 (13) | 505 (12) | *** | 15 |
| Lungs | 814 (30) | - | 1001 (21) | *** | 36 |
| Pizzle | 318 (8) | - | 446 (13) | *** | 16 |
| Head | 1663 (19) | - | 2160 (52) | *** | 55 |
| Gut | 3496 (105) | 4092 (125) | 4324 (145) | *** | 178 |
| Total | 12880 (240) | 15070 (435) | 16750 (354) | *** | 16 |

1,2 See footnotes 4 and 5, Table 4.1

**Table 4.12.** The weight of the non-carcass body components for the three age groups expressed as a percentage of empty body weight. [Mean values (SE)]

| Non-carcass component | Group | | | Significance of difference[1] | SED[2] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Blood | 4.31 (0.27) | - | 4.18 (0.20) | NS | 0.34 |
| Hide | 6.3 (0.1) | 6.3 (0.1) | 6.5 (0.1) | NS | 0.2 |
| Legs | 2.91 (0.02) | 2.70 (0.02) | 2.47 (0.02) | *** | 0.03 |
| Liver | 1.86 (0.03) | 1.86 (0.03) | 1.74 (0.03) | * | 0.04 |
| Heart | 0.92 (0.01) | 0.87 (0.02) | 0.91 (0.01) | NS | 0.02 |
| Lungs | 2.02 (0.07) | - | 1.80 (0.04) | * | 0.08 |
| Pizzle | 0.79 (0.02) | - | 0.80 (0.02) | NS | 0.03 |
| Head | 4.12 (0.04) | - | 3.88 (0.08) | * | 0.09 |
| Gut | 8.66 (0.20) | 9.23 (0.14) | 7.55 (0.19) | *** | 0.25 |
| Total | 31.9 (0.3) | 34.0 (0.4) | 30.0 (0.3) | *** | 0.4 |

1,2 See footnotes 4 and 5, Table 4.1

**Table 4.13.** Linear regression analyses and allometric growth coefficients of the non-carcass body components relative to EBW.[1]

| Non-carcass Component | Linear Regression | | | | | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | a | $SE_a$ | b | $SE_b$ | $r^2$ | b | $SE_b$ | $r^2$ | |
| Blood† | 0.015 | 0.464 | 0.042 | 0.010 | 0.58 | 1.01 | 0.25 | 0.53 | A |
| Hide | -0.155 | 0.185 | 0.673 | 0.004 | 0.93 | 1.06 | 0.07 | 0.92 | A |
| Legs | 0.570 | 0.041 | 0.015 | 0.001 | 0.93 | 0.55*** | 0.04 | 0.92 | L |
| Liver | 0.185 | 0.055 | 0.014 | 0.001 | 0.87 | 0.78** | 0.06 | 0.87 | A |
| Heart | -0.002 | 0.031 | 0.009 | 0.001 | 0.90 | 0.99 | 0.08 | 0.89 | A |
| Lungs† | 0.344 | 0.106 | 0.012 | 0.002 | 0.68 | 0.64** | 0.12 | 0.68 | L |
| Pizzle† | 0.000 5 | 0.0472 | 0.0079 | 0.0009 | 0.83 | 1.01 | 0.12 | 0.83 | A |
| Head† | 0.402 | 0.143 | 0.031 | 0.003 | 0.89 | 0.79** | 0.06 | 0.92 | L |
| Gut | 1.492 | 0.445 | 0.053 | 0.009 | 0.59 | 0.66** | 0.11 | 0.60 | L |
| Total non-carcass components | 3.60 | 1.03 | 0.241 | 0.022 | 0.85 | 0.79** | 0.07 | 0.86 | L |

†Group II data not included
[1]See footnotes Table 4.5

## 4.4 RELATIVE MUSCLE GROWTH

### 4.4.1 Carcass Cuts and Some Individual Muscles

The growth pattern of total muscle relative to other carcass components was described in section 4.2.1. In this section the growth pattern of selected individual muscles and muscle groups is presented (Table 4.14). Table 4.15 shows the weights of these muscles and muscle groups expressed as percentagesof total side muscle weight.

With the exception of the flank muscle both the average weight of muscle in each of the carcass cuts and the weight of the individual muscles increased across the three age groups (Table 4.14). The differences between the weight of muscle for the M13 and M17 groups were not statisitcally significant ($P<0.05$) in the case of the flank, haunch and individual muscles in the haunch.

The percentage of total neck muscle showed no linear trend between age groups with group M25 being greater than M13, but the group M17 had the greatest percentage neck muscle. However the percentage of the individual neck muscles m. splenius and m. semispinalis did increase across the age groups. There was no consistent age group effect on the percentage of muscle in the shoulder although it was significantly higher in the M17 group than in the other groups. There was no difference between the age groups in the percentages of muscle in either the saddle or m. longissimus, but in the M17 group the percentage of muscle in flank was lower. With the saddle and flank combined there was no significant difference in the percentage of muscle in this region of the carcass between groups. The percentage weight of total muscle and individually weighed muscles

**Table 4.14.** The weight of total side muscle, muscle in side cuts, and individually recorded muscles (g) for the three age groups. [Mean values (SE)]

| Muscle component | Group | | | Significance of difference[1] | SED[2] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Neck | 958 (52) | 1300 (44) | 1460 (33) | *** | 61.5 |
| *M. splenius* | 28 (1) | 42 (3) | 55 (3) | *** | 2.98 |
| *M. semispinalis* | 64 (2) | 79 (7) | 110 (3) | *** | 6.32 |
| Shoulder | 1609 (32) | 1817 (49) | 2143 (44) | *** | 59.8 |
| Saddle | 1418 (38) | 1637 (47) | 1991 (44) | *** | 61.3 |
| *M. longissimus* | 820 (17) | 894 (22) | 1155 (25) | *** | 30.8 |
| Flank | 1326 (50) | 1314 (33) | 1790 (46) | *** | 62.8 |
| Saddle + flank | 2745 (59) | 2951 (69) | 3781 (79) | *** | 99 |
| Haunch | 3975 (71) | 4109 (88) | 5249 (93) | *** | 119 |
| *M. semitendinosus* | 190 (5) | 197 (4) | 261 (6) | *** | 7.4 |
| *M. semimembranosus* | 646 (8) | 652 (17) | 856 (12) | *** | 18.6 |
| *M. gluteobiceps* | 716 (10) | 758 (18) | 999 (19) | *** | 23.0 |
| *M. quadriceps femoris* | 825 (20) | 851 (18) | 1067 (19) | *** | 26.6 |
| Total side | 9286 (174) | 10177 (218) | 12634 (226) | *** | 294 |

1,2 See footnotes 4 and 5, Table 4.1

**Table 4.15.** The weight of the side cuts muscle and individually recorded muscles for the three age groups expressed as a percentage of total side muscle weight. [Mean values (SE)]

| Muscle component | Group | | | Significance of difference[1] | SED[2] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Neck | 10.3 (0.5) | 12.8 (0.3) | 11.6 (0.1) | *** | 0.45 |
| M. splenius | 0.30 (0.01) | 0.42 (0.02) | 0.43 (0.01) | *** | 0.02 |
| M. semispinalis | 0.69 (0.02) | 0.78 (0.06) | 0.87 (0.02) | * | 0.06 |
| Shoulder | 17.3 (0.1) | 17.9 (0.4) | 17.0 (0.1) | * | 0.33 |
| Saddle | 15.3 (0.4) | 16.1 (0.2) | 15.8 (0.3) | NS | - |
| M. longissimus | 8.8 (0.2) | 8.8 (0.1) | 9.1 (0.1) | NS | - |
| Flank | 14.3 (0.5) | 12.9 (0.2) | 14.2 (0.2) | * | 0.49 |
| Saddle + flank | 29.6 (0.5) | 29.0 (0.2) | 30.0 (0.3) | NS | - |
| Haunch | 42.8 (0.2) | 40.4 (0.2) | 41.6 (0.2) | *** | 0.29 |
| M. semitendinosus | 2.04 (0.01) | 1.94 (0.01) | 2.07 (0.03) | ** | 0.03 |
| M. semimembranosus | 6.96 (0.06) | 6.40 (0.07) | 6.78 (0.04) | *** | 0.08 |
| M. gluteobiceps | 7.71 (0.05) | 7.44 (0.06) | 7.91 (0.05) | *** | 0.07 |
| M. quadriceps femoris | 8.89 (0.15) | 8.37 (0.07) | 8.44 (0.07) | ** | 0.15 |

1,2 See footnotes 4 and 5, Table 4.1

in the haunch was consistently the lowest for the M17 group and generally decreased from M13 to M25 except for the m. gluteobiceps. The possible effects of season of slaughter on the above result is described in section 4.7.

The trends in muscle component growth relative to total side muscle are given by the allometric growth coefficients in Table 4.16. The m. splenius and m. semispinalis muscles are each classified as having high growth impetus relative to total side muscle whereas the total neck muscles had an average growth impetus relative to total side muscle.

**Table 4.16.** The allometric growth coefficients and growth impetus classes of muscle of the carcass cuts and individual muscles relative to total side muscle weight.[1]

| Side cut | Allometric Growth Coefficient b | $SE_b$ | $r^2$ | Relative growth impetus |
|---|---|---|---|---|
| Neck | 1.28 | 0.18 | 0.70 | A |
| *M. splenius* | 2.00*** | 0.20 | 0.81 | H |
| *M. semispinalis* | 1.60* | 0.25 | 0.66 | H |
| Shoulder | 0.91 | 0.06 | 0.92 | A |
| Saddle | 1.05 | 0.08 | 0.88 | A |
| *M. longissimus* | 1.10 | 0.06 | 0.94 | A |
| Flank | 1.05 | 0.12 | 0.77 | A |
| Saddle + flank | 1.05 | 0.05 | 0.95 | A |
| Haunch | 0.94 | 0.04 | 0.96 | A |
| *M. semitendinosus* | 1.09 | 0.06 | 0.94 | A |
| *M. semimembranosus* | 0.96 | 0.06 | 0.94 | A |
| *M. gluteobiceps* | 1.09* | 0.04 | 0.97 | H |
| *M. quadriceps femoris* | 0.88* | 0.06 | 0.92 | L |

[1]See footnotes 2 and 3, Table 4.5

The shoulder, saddle (including the *m. longissimus*) and flank muscles each showed an average growth impetus and the growth pattern exhibited by the muscles in the haunch was variable.

### 4.4.2 Eye-Muscle Area (EMA)

The mean EMAs and standard errors were 22.1 (0.6), 22.3 (0.7) and 25.9 (0.7) $cm^2$ for groups M13, M17 and M25 respectively (SED = 1.3). Group M25 EMA was significantly greater than that for groups M13 ($P<0.01$) and M17 ($P<0.05$) with no significant difference between

groups M13 and M17 EMAs. The logarithmic regression of EMA on total carcass muscle weight gave a b-value of 0.60 ± 0.10 ($r^2$ = 0.63).

### 4.4.3 Chemical Composition

The chemical composition of the muscle tissue for the three age groups expressed as a percentage of total side muscles is given in Table 4.17. From the allometric coefficients it appears that with increasing side muscle weight water became a decreasing proportion and lipid an increasing proportion of the muscle by weight, while the ash and protein components remained in constant proportion.

The mean chemical compositions of four individual muscles expressed as percentages of the weight of each muscle are presented for each group in Table 4.18.

Chemical composition of each of the individual muscles studied showed similar trends between age groups. Protein content was highest and lipid content lowest in all muscles in the M17 group. There were no differences between groups for ash content in any muscles and water content tended to be higher in M13 followed by M25. However differences were not significant for m. gluteobiceps and the differences between M17 and M25 water content were not significantly different for the m. longissimus and m. semispinalis.

**Table 4.17.** Chemical composition of muscle tissue for the three age groups expressed as a percentage of total side muscle [mean values (SE)] together with allometric growth coefficients and growth impetus classes of the chemical components relative to total side muscle weight.[1]

| Chemical Component | Group | | | Significance of difference[2] | SED[3] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | M13 | M17 | M25 | | | b | $SE_b$ | $r^2$ | |
| Water | 75.4 (0.1) | 74.6 (0.1) | 74.7 (0.1) | *** | 0.16 | 0.98* | 0.01 | 0.99 | L |
| Lipid | 1.4 (0.1) | 1.4 (0.1) | 1.7 (0.1) | ** | 0.10 | 1.69** | 0.22 | 0.72 | H |
| Ash | 1.10 (0.02) | 1.16 (0.01) | 1.10 (0.01) | * | 0.02 | 0.99 | 0.07 | 0.91 | A |
| Protein | 22.1 (0.1) | 22.9 (0.1) | 22.5 (0.1) | *** | 0.13 | 1.02 | 0.03 | 0.99 | A |

[1]See footnotes 2 and 3, Table 4.5
[2,3] See footnotes 4 and 5, Table 4.1

**Table 4.18.** The chemical components of the individual muscles within age group, expressed as percentages of each muscle's weight. [Mean values (SE)]

| Muscle | Group | | | Significance of difference[1] | SED[2] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| M. semispinalis | | | | | |
| water | 76.8 (0.2) | 76.1 (0.1) | 76.0 (0.2) | ** | 0.26 |
| lipid | 1.2 (0.1) | 1.1 (0.1) | 1.4 (0.1) | * | 0.10 |
| ash | 1.05 (0.02) | 1.07 (0.01) | 1.06 (0.01) | NS | 0.02 |
| protein | 20.9 (0.1) | 21.8 (0.2) | 21.6 (0.2) | ** | 0.23 |
| M. longissimus | | | | | |
| water | 75.4 (0.2) | 74.5 (0.1) | 74.9 (0.1) | ** | 0.23 |
| lipid | 0.64 (0.07) | 0.58 (0.04) | 0.81 (0.05) | NS | 0.07 |
| ash | 1.20 (0.04) | 1.30 (0.04) | 1.21 (0.03) | NS | 0.05 |
| protein | 22.8 (0.2) | 23.6 (0.1) | 23.1 (0.1) | ** | 0.20 |
| M. semimembranosus | | | | | |
| water | 75.2 (0.2) | 74.1 (0.1) | 75.0 (0.1) | *** | 0.19 |
| lipid | 0.57 (0.03) | 0.50 (0.04) | 0.68 (0.05) | * | 0.06 |
| ash | 1.24 (0.06) | 1.36 (0.04) | 1.28 (0.04) | NS | 0.07 |
| protein | 23.0 (0.1) | 24.1 (0.1) | 23.0 (0.1) | *** | 0.17 |
| M. gluteobiceps | | | | | |
| water | 75.7 (0.2) | 75.2 (0.1) | 75.4 (0.1) | NS | 0.18 |
| lipid | 0.68 (0.05) | 0.56 (0.03) | 0.92 (0.05) | *** | 0.06 |
| ash | 1.22 (0.03) | 1.30 (0.04) | 1.21 (0.01) | NS | 0.04 |
| protein | 22.4 (0.1) | 22.9 (0.1) | 22.5 (0.1) | * | 0.16 |

1,2 See footnotes 4 and 5, Table 4.1

## 4.5 RELATIVE BONE GROWTH

### 4.5.1 Carcass Cuts and Some Individual Bones

The growth of bone in comparison to other carcass components is described in section 4.2.1. Here the weights of individual bones and bone groups are presented (Table 4.19). The weights of these bones expressed as percentages of total side bone weight are shown in Table 4.20.

**Table 4.19.** The weight of side bone, cut bone, and individually recorded bones (g) for the three age groups. [Mean values (SE)]

| Bone Component | Group M13 | Group M17 | Group M25 | Significance of difference[1] | SED[2] |
|---|---|---|---|---|---|
| Neck bone | 292 (17) | 323 (20) | 370 (17) | * | 25.2 |
| Shoulder bone | 373 (6) | 397 (9) | 468 (10) | *** | 11.6 |
| Metacarpal | 81 (2) | 91 (2) | 88 (1) | * | 2.4 |
| Radius + Ulna | 123 (2) | 131 (3) | 153 (2) | *** | 3.4 |
| Humerus | 160 (2) | 169 (4) | 200 (4) | *** | 4.8 |
| Scapula | 88 (2) | 98 (3) | 116 (4) | *** | 4.4 |
| Saddle bone | 281 (26) | 273 (13) | 364 (19) | ** | 28.4 |
| Flank bone | 230 (9) | 228 (6) | 296 (7) | *** | 10.8 |
| Haunch bone | 611 (14) | 633 (12) | 718 (15) | *** | 19.6 |
| Femur | 229 (4) | 233 (5) | 268 (5) | *** | 6.2 |
| Tibia + Tarsus | 193 (4) | 196 (4) | 234 (4) | *** | 5.3 |
| Total side bone | 1785 (43) | 1854 (43) | 2216 (43) | *** | 60 |

1,2 See footnotes 4 and 5, Table 4.1

Both the total weight of bone in each cut and the weight of each individually recorded bone increased between the M13 and M25 age groups, although differences between the M13 and M17 groups were not

always significant. The percentage of bone in each cut was however the same for each age group except in the haunch. The percentage of total bone in the haunch decreased between M13 and M25 due in part to the decreasing percentage weight of the femur (see Table 4.20).

The above results are reflected in the allometric growth coefficients for bone growth where total side bone was used as the independent variate (Table 4.20).

The tibia plus tarsus, femur and total haunch bone were each classed as having a low growth impetus relative to total bone, while each of the other bone components had an average relative growth impetus. Since the tibia plus tarsus and femur represented approximately 68% of the total haunch bone by weight they had a major influence on the overall growth impetus of total haunch bone. The other haunch bones had an average growth impetus ($b=0.76$, $SE_b=0.19$), but there was a large standard error associated with this allometric growth coefficient. Although not a part of the total carcass bone, the metacarpal was also classed as having a low growth impetus relative to total bone.

### 4.5.2 Bone Dimensions

The length of three bones, the metacarpal, humerus and femur was measured and found to increase between groups M13 and M25 (Table 4.21), but differences between M13 and M17 were not significant for all three bones.

The circumference of the metacarpal was not significantly different between age groups (Table 4.21). Bone dimension had a low growth impetus relative to carcass length for the metacarpal bone, but

length of the femur and humerus remained in similar proportion to carcass length as the latter increased.

**Table 4.20.** The weight of the side cuts bone and individually recorded bones for each age group expressed as a percentage of total side bone weight together with allometric growth coefficients and growth impetus of bones relative to total side bone weight.[1] [Mean values (SE)]

| Bone Component | Group | | | Signif. of diff. | SED | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | M13 | M17 | M25 | | | b | $SE_b$ | $r^2$ | |
| Neck bone | 16.3 (0.7) | 17.4 (0.9) | 16.7 (0.5) | NS | 1.00 | 1.25 | 0.21 | 0.61 | A |
| Shoulder bone | 20.8 (0.5) | 21.4 (0.3) | 21.1 (0.3) | NS | 0.51 | 0.90 | 0.09 | 0.83 | A |
| Metacarpal | 81 (2) | 81 (2) | 88 (1) | * | 2 | 0.33*** | 0.10 | 0.31 | L |
| Radius + Ulna | 6.9 (0.2) | 7.1 (0.1) | 6.9 (0.1) | NS | 0.18 | 0.83 | 0.09 | 0.81 | A |
| Humerus | 9.0 (0.2) | 9.1 (0.1) | 9.0 (0.1) | NS | 0.21 | 0.88 | 0.08 | 0.85 | A |
| Scapula | 4.9 (0.1) | 5.3 (0.1) | 5.2 (0.2) | NS | 0.20 | 1.03 | 0.29 | 0.49 | A |
| Saddle bone | 15.7 (1.3) | 14.7 (0.5) | 16.4 (0.8) | NS | 1.30 | 1.35 | 0.29 | 0.49 | A |
| Flank bone | 13.0 (0.6) | 12.3 (0.2) | 13.4 (0.2) | NS | 0.53 | 1.07 | 0.16 | 0.66 | A |
| Haunch bone | 34.3 (0.4) | 34.2 (0.3) | 32.4 (0.4) | ** | 0.50 | 0.76*** | 0.05 | 0.91 | L |
| Femur | 12.8 (0.2) | 12.6 (0.2) | 12.1 (0.1) | * | 0.23 | 0.82* | 0.07 | 0.85 | L |
| Tibia + Tarsus | 10.9 (0.2) | 10.6 (0.1) | 10.6 (0.2) | NS | 0.23 | 0.73*** | 0.05 | 0.89 | L |

[1] See footnotes 2 and 3, Table 4.5

**Table 4.21.** Bone dimensions (mm) for the three age groups [mean values (SE)] and allometric growth coefficients and growth impetus of these bone dimensions relative to carcass length (LB) for groups M13 and M25.[1]

| Bone dimension | Group | | | Signif. of diff.[2] | SED[3] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | M13 | M17 | M25 | | | b | $SE_b$ | $r^2$ | |
| Metacarpal | | | | | | | | | |
| length | 185 (1) | 185 (2) | 191 (2) | * | 2.2 | 0.28*** | 0.13 | 0.25 | L |
| circumference | 59.8 (0.8) | 62.0 (0.8) | 61.4 (1.0) | NS | 1.2 | 0.28*** | 0.23 | 0.10 | L |
| Humerus | | | | | | | | | |
| length | 175 (2) | 178 (2) | 188 (1) | *** | 2.1 | 0.85 | 0.10 | 0.84 | A |
| Femur | | | | | | | | | |
| length | 227 (2) | 231 (2) | 246 (2) | *** | 4.9 | 0.90 | 0.05 | 0.96 | A |

[1]See footnotes 2 and 3, Table 4.5
[2,3] See footnotes 4 and 5, Table 4.1

### 4.5.3 Chemical Composition

The chemical composition of total side bone for each age group is presented in Table 4.22. There was no difference between groups in the percentage of protein in bones, but both ash and lipid contents increased and water content decreased between M13 and M17. Differences between M17 and M25 were not significant.

However allometric growth analyses suggested that only the ash content of bones differed significantly with increasing bone weight, and that percentage ash increased as bone weight increased (Table 4.22).

**Table 4.22.** Chemical composition of bone tissue for the age groups expressed as a percentage of total side bone [mean values (SE)] and the growth coefficients and growth impetus of the chemical components relative to total side bone.[1]

| Chemical Component | Group | | | | | | Significance of difference[2] | SED[3] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M13 | | M17 | | M25 | | | | b | $SE_b$ | $r^2$ | |
| Water | 35 | (2) | 31 | (1) | 31 | (1) | *** | 0.69 | 0.78 | 0.12 | 0.65 | A |
| Lipid | 12 | (1) | 14 | (1) | 13 | (1) | * | 0.43 | 1.04 | 0.15 | 0.69 | A |
| Ash | 30 | (2) | 32 | (1) | 33 | (1) | *** | 0.63 | 1.24* | 0.10 | 0.88 | H |
| Protein | 23.4 | (0.2) | 23.9 | (0.2) | 23.7 | (0.2) | NS | 0.29 | 0.97 | 0.05 | 0.95 | A |

[1]See footnotes 2 and 3, Table 4.5
[2,3] See footnotes 4 and 5, Table 4.1

## 4.6 RELATIVE FAT GROWTH

### 4.6.1 Carcass Cuts Total Fat

The weight of total dissectible fat in each cut is shown in Table 4.23. Total fat in each cut increased between all groups from M13 to M25 except for weight of fat in the neck between M17 and M25, and shoulder fat weight where M13 and M17 groups did not differ significantly.

**Table 4.23.** The weight of total fat[1] in each of the side cuts. [Mean values (SE)]

| Side cut | Group | | | Significance of difference[2] | SED[3] |
|---|---|---|---|---|---|
| | M13 | M17 | M25 | | |
| Neck | 59 (5) | 114 (11) | 109 (9) | *** | 13 |
| Shoulder | 168 (14) | 173 (10) | 285 (16) | *** | 19 |
| Saddle | 125 (15) | 200 (12) | 312 (34) | *** | 32 |
| Flank | 276 (20) | 399 (19) | 741 (45) | *** | 43 |
| Haunch | 276 (18) | 343 (15) | 611 (45) | *** | 41 |
| Total side | 904 (66) | 1228 (56) | 2044 (133) | *** | 141 |

[1]Sum of subcutaneous and intermuscular fat
[2,3] See footnotes 4 and 5, Table 4.1

The percentage of total fat in the carcass was greatest in the flank and haunch cuts and least in the neck for all age groups (Table 4.24). Allometric growth analyses for total fat showed the percentage increase in fat in the neck, and haunch to be similar to that in the total carcass but fat growth in the shoulder and flank and saddle cuts had low and high growth impetuses, respectively, relative to total fat growth.

**Table 4.24.** Weight of total fat[1] in side cuts for each age group expressed as a percentage of total side fat [mean value (SE)], together with allometric growth coefficients.[2]

| Chemical Component | Group | | | Significance of difference[3] | SED[4] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|
| | M13 | M17 | M25 | | | b | $SE_b$ | $r^2$ | |
| Neck | 6.6 (0.3) | 9.2 (0.7) | 5.4 (0.5) | *** | 0.7 | 0.72 | 0.16 | 0.49 | A |
| Shoulder | 18.5 (0.8) | 14.1 (0.6) | 14.0 (0.3) | *** | 0.8 | 0.75*** | 0.07 | 0.82 | L |
| Saddle | 13.9 (0.9) | 16.2 (0.5) | 15.2 (1.1) | NS | 1.2 | 1.20* | 0.09 | 0.89 | H |
| Flank | 30.7 (1.0) | 32.6 (0.7) | 36.3 (0.8) | *** | 1.2 | 1.14** | 0.05 | 0.97 | H |
| Haunch | 30.5 (0.7) | 28.0 (0.6) | 29.3 (0.7) | * | 1.0 | 0.96 | 0.04 | 0.96 | A |

[1]Sum of subcutaneous and intermuscular fat
[2]See footnotes 2 and 3, Table 4.5
[3,4] See footnotes 4 and 5, Table 4.1

### 4.6.2 Subcutaneous and Intermuscular Fat

To investigate the pattern of fat growth further it was necessary to partition fat growth between subcutaneous (SQ) and intermuscular (IM) fat growth.

Intermuscular fat made up the greatest proportion of total fat in the carcass over the carcass weight range studied (Table 4.25). The same pattern existed in each of the cuts except in the haunch, and in the M25 group, the saddle. These latter cuts had a greater proportion of total fat as subcutaneous fat.

**Table 4.25.** The weight of subcutaneous and intermuscular fat in each of the side cuts and the total side, for the age groups. [Mean values (SE)]

| Cut | Fat depot[1] | Group M13 | Group M17 | Group M25 | Significance of difference[2] | SED[3] |
|---|---|---|---|---|---|---|
| Neck | - IM | 59 (5) | 114 (11) | 109 (9) | *** | 13 |
| Shoulder | - SQ | 29 (5) | 42 (5) | 82 (13) | *** | 12 |
| | - IM | 138 (13) | 131 (9) | 203 (9) | *** | 15 |
| Saddle | - SQ | 47 (7) | 84 (7) | 176 (27) | *** | 23 |
| | - IM | 79 (9) | 116 (6) | 136 (12) | *** | 13 |
| Flank | - SQ | 109 (7) | 172 (13) | 344 (33) | *** | 29 |
| | - IM | 168 (13) | 227 (9) | 397 (15) | *** | 18 |
| Haunch | - SQ | 143 (12) | 166 (8) | 384 (26) | *** | 24 |
| | - IM | 133 (7) | 177 (9) | 214 (10) | *** | 12 |
| Total side | - SQ | 327 (27) | 464 (29) | 986 (88) | *** | 79 |
| | - IM | 577 (41) | 765 (30) | 1058 (41) | *** | 53 |

[1]SQ = subcutaneous, IM = intermuscular
[2,3] See footnotes 4 and 5, Table 4.1

As carcass weight increased from 25 to 36 kg however, the weight of subcutaneous fat as a percentage of total carcass fat increased from 36 to 48% while intermuscular fat decreased from 64 to 52%. Allometric growth coefficients for total side subcutaneous and intermuscular fat relative to total side fat where 1.32 and 0.76 respectively (Table 4.26). Similar trends in allometric growth coefficients for subcutaneous and intermuscular fat relative to total fat occurred in the individual cuts as in the total carcass. That is subcutaneous fat in each cut showed average or high growth impetus (except in the neck where no subcutaneous fat was recognised) and intermuscular fat showed average or low growth impetus. However, to compare the growth impetus of subcutaneous and intermuscular fat in individual cuts relative to total side subcutaneous or intermuscular fat it was necessary to derive the appropriate allometric growth coefficients for these relationships (Table 4.27).

From Table 4.27 it can be seen that by far the greatest proportions of carcass subcutaneous fat were present in the haunch (36-44%) and flank (33-37%). However as carcass weight increased the greatest percentage increase in subcutaneous fat occurred in the saddle (AGC=1.26, Table 4.27). The growth impetus of subcutaneous fat on the shoulder and flank remained similar to total subcutaneous fat growth and for the haunch it was classified as slightly below average.

The greatest amount of intermuscular fat was present in the flank (29-38%) where its growth impetus relative to total intermuscular fat was high (AGC=1.29, Table 4.27). The shoulder and haunch had intermediate amounts of intermuscular fat with average and low growth impetuses respectively although the allometric growth coefficient of

the former was low, 0.75, but had a high standard error associated with the estimate.

Finally the lowest percentages of total intermuscular fat were found in the neck and saddle, where it had average growth impetuses.

**Table 4.26.** The weight of subcutaneous and intermuscular fat in the side cuts and total side for the age groups expressed as a percentage of total side fat[1] [mean values (SE)] together with allometric growth coefficients.[2]

| Cut | Fat depot[3] | Group | | | Signif. of diff.[4] | SED[5] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|---|
| | | M13 | M17 | M25 | | | b | $SE_b$ | $r^2$ | |
| Neck | IM | 6.6 (0.3) | 9.2 (0.7) | 5.4 (0.4) | *** | 0.7 | 0.72 | 0.16 | 0.49 | A |
| Shoulder | SQ | 3.2 (0.4) | 3.4 (0.3) | 3.9 (0.5) | NS | 0.6 | 1.31 | 0.17 | 0.73 | A |
| | IM | 15.4 (0.9) | 10.7 (0.6) | 10.0 (0.4) | *** | 0.9 | 0.58*** | 0.10 | 0.63 | L |
| Saddle | SQ | 5.0 (0.5) | 6.8 (0.4) | 8.4 (0.9) | ** | 0.9 | 1.67*** | 0.13 | 0.89 | H |
| | IM | 8.5 (0.5) | 9.5 (0.4) | 6.7 (0.5) | ** | 0.7 | 0.77 | 0.12 | 0.66 | A |
| Flank | SQ | 12.1 (0.4) | 13.9 (0.6) | 16.7 (0.8) | *** | 0.9 | 1.31*** | 0.07 | 0.94 | H |
| | IM | 18.6 (0.7) | 18.6 (0.7) | 19.6 (0.6) | NS | 0.9 | 1.02 | 0.05 | 0.94 | A |
| Haunch | SQ | 15.8 (0.6) | 13.5 (0.2) | 18.8 (0.5) | *** | 0.6 | 1.21** | 0.07 | 0.93 | H |
| | IM | 14.7 (0.6) | 14.5 (0.7) | 10.5 (0.4) | *** | 0.8 | 0.57*** | 0.054 | 0.84 | L |
| Total side | SQ | 36.1 (1.1) | 37.6 (1.1) | 48.2 (1.7) | *** | 1.9 | 1.32*** | 0.05 | 0.97 | H |
| | IM | 63.9 (1.1) | 62.4 (1.1) | 51.8 (1.7) | *** | 1.9 | 0.76*** | 0.04 | 0.96 | L |

[1]Sum of subcutaneous and intermuscular fat
[2]See footnotes 2 and 3, Table 4.5
[3]SQ - subcutaneous, IM = intermuscular
[4,5] See footnotes 4 and 5, Table 4.1

Table 4.27. The weights of subcutaneous and intermuscular fat within each cut expressed as percentages of total side subcutaneous and intermuscular fat respectively within the three age groups ([mean values (SE)] together with allometric growth coefficients.[1]

| Cut | Fat depot[2] | Group | | | Signif. of diff.[3] | SED[4] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|---|
| | | M13 | M17 | M25 | | | b | $SE_b$ | $r^2$ | |
| Neck | IM | 10.3 (0.4) | 14.7 (1.2) | 10.2 (0.8) | ** | 1.2 | 1.05 | 0.18 | 0.62 | A |
| Shoulder | SQ | 8.7 (0.9) | 8.9 (0.7) | 8.2 (0.9) | NS | 1.2 | 1.01 | 0.12 | 0.78 | A |
| | IM | 24.0 (1.3) | 17.1 (0.8) | 19.2 (0.6) | *** | 1.3 | 0.75 | 0.12 | 0.63 | A |
| Saddle | SQ | 14.4 (1.1) | 18.0 (0.8) | 17.8 (1.6) | * | 1.7 | 1.26** | 0.09 | 0.91 | H |
| | IM | 13.3 (0.9) | 15.2 (0.6) | 12.8 (0.9) | NS | 1.1 | 1.06 | 0.13 | 0.76 | A |
| Flank | SQ | 33.3 (1.3) | 37.0 (0.9) | 35.1 (1.7) | NS | 1.9 | 0.98 | 0.05 | 0.95 | A |
| | IM | 29.1 (1.2) | 29.8 (0.9) | 37.6 (0.6) | *** | 1.27 | 1.29** | 0.08 | 0.92 | H |
| Haunch | SQ | 43.7 (1.4) | 36.1 (0.9) | 38.9 (0.8) | *** | 1.5 | 0.91* | 0.04 | 0.96 | L |
| | IM | 23.1 (0.8) | 23.1 (0.8) | 20.3 (0.6) | * | 1.0 | 0.76*** | 0.06 | 0.89 | L |

[1]See footnotes 2 and 3, Table 4.5
[2]SQ = subcutaneous, IM = intermuscular
[3,4] See footnotes 4 and 5, Table 4.1

### 4.6.3 Relationships Between Back-fat Depth and Carcass Fatness

The back-fat depth 'C' for the three groups and the growth coefficients and growth impetus of 'C' relative to SQ fat, total fat and side weight are given in Table 4.28. The fat depth 'C' appeared to increase with increasing carcass weight, but only appreciably at the higher carcass weights.

The AGCs for the relationships are all greater than one but are also associated with high standard errors. The growth impetus of 'C' relative to SQ fat, total fat and sideweight is described as average, high and high respectively.

The relationship between carcass weight (x) and back-fat depth 'C' (y) is described by the equation

| | SEa | SEb | $r^2$ | |
|---|---|---|---|---|
| $y = -6.73 + 0.309\ x$ | 1.128 | 0.037 | 0.078 | (4.2) |

**Table 4.28.** Fat depth 'C' for the slaughter groups and allometric growth coefficient and growth impetus of fat depth 'C' relative to total subcutaneous fat, total fat and side weight [mean (SE)].

| | Group | | | |
|---|---|---|---|---|
| | M13 | M17 | M25 | SED |
| Fat Depth 'C' | 1.3 (0.2) | 1.4 (0.1) | 4.8 (0.4) | 0.40 |

| Independent variate | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|
| | b | SEb | $r^2$ | |
| Total subcutaneous fat | 1.21 | 0.11 | 0.84 | A |
| Total fat | 1.58** | 0.17 | 0.79 | H |
| Side weight | 3.62*** | 0.45 | 0.75 | H |

### 4.6.4 Chemical Composition

The chemical composition of total side subcutaneous and intermuscular fat are shown in Table 4.29. The lipid content of subcutaneous fat increased between M13 and M25 while the water, protein and ash contents all decreased. These trends resulted in allometric growth coefficients significantly greater than one for subcutaneous lipids and less than one for other chemical components. Exactly the same trends emerged for intermuscular fat with the exception of the ash content which was higher for the M17 group than for the M13 group.

**Table 4.29.** Chemical composition of subcutaneous and intermuscular fat for the slaughter groups expressed as a percentage of total side subcutaneous and intermuscular fat respectively [mean values (SE)]. And the allometric growth coefficients and growth impetus classes for the chemical components relative to total side subcutaneous and intermuscular fat respectively.[1]

| | Group | | | | | | Significance of difference[2] | SED[3] | Allometric Growth Coefficient | | | Relative growth impetus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M13 | | M17 | | M25 | | | | b | $SE_b$ | $r^2$ | |
| Subcutaneous fat | | | | | | | | | | | | |
| Water | 42 | (3) | 30 | (2) | 24 | (2) | *** | 3.08 | 0.50*** | 0.06 | 0.75 | L |
| Lipid | 45 | (4) | 59 | (2) | 69 | (3) | *** | 4.18 | 1.41*** | 0.06 | 0.97 | H |
| Ash | 0.53 | (0.04) | 0.43 | (0.02) | 0.29 | (0.03) | *** | 0.04 | 0.45*** | 0.07 | 0.66 | L |
| Protein | 12.6 | (1.0) | 10.9 | (0.7) | 6.7 | (0.8 | *** | 1.17 | 0.38*** | 0.07 | 0.60 | L |
| Intermuscular fat | | | | | | | | | | | | |
| Water | 43 | (1) | 41 | (1) | 38 | (1) | * | 1.82 | 0.85* | 0.07 | 0.89 | L |
| Lipid | 44 | (2) | 46 | (2) | 51 | (2) | * | 2.47 | 1.22** | 0.07 | 0.93 | H |
| Ash | 0.58 | (0.03) | 0.66 | (0.03) | 0.53 | (0.02) | ** | 0.04 | 0.81 | 0.10 | 0.73 | A |
| Protein | 12.6 | (1.1) | 11.9 | (0.4) | 10.5 | (0.7) | NS | 1.09 | 0.68** | 0.11 | 0.65 | L |

[1] See footnotes 2 and 3, Table 4.5
[2/3] See footnotes 4 and 5, Table 4.1

## 4.7 ANALYSIS BY SEASON OF SLAUGHTER

In a number of previous analyses it was noted that individual muscles in group M17 did not always show the same trend with increasing age or carcass weight as was apparent between groups M13 and M25. The possibility of a season of slaughter effect (nonrut versus midrut) on these was therefore analysed, where season was fitted as a covariate (0 for groups M13 and M25, 1 for group M17) for the previous analyses using multiple regression techniques.

Season of slaughter did not add significantly to carcass weight in explaining weight of total side muscle, SQ fat, IM fat, total fat, bone or kidney fat. Season was also not a significant covariate when paired with side bone weight in explaining the variation in individual bone weights (femur, humerus, radius + ulna, scapula, tibia + tarsus). However, season was a significant covariate when added to side muscle weight in explaining variation in the individual muscle weights of the mm splenius ($P \leq 0.01$), semitendinosus ($P \leq 0.01$), semimembranosus ($P \leq 0.01$), gluteobiceps ($P \leq 0.001$) and quadriceps femoris ($P \leq 0.01$). The apparent effect of season was to reduce the weight of the ST, SM, GB, and QF and increase the weight of the SP of animals in May compared to animals of equivalent side muscle weight slaughtered in January (nonrut period) (Table 4.30).

**Table 4.30.** Coefficients for the 'season' covariate ($b_2$) when paired with side muscle weight ($b_1$) in individual muscle weight analyses where $x_2$ equals 1 for rut and 0 for non-rut

| Dependent variable (y) | Regression coefficients | | $r^2$ |
|---|---|---|---|
| | $b_1$ | $b_2$[1] | |
| M. splenius | 0.0080 (0.0006) | + 7.39 (1.85)** | 90.3 |
| M. semitendinosus | 0.021 (0.001) | -11.5 (3.3)** | 96.2 |
| M. semimembranosus | 0.062 (0.002) | -50.8 (6.9)** | 98.1 |
| M. gluteobiceps | 0.083 (0.002) | -34.8 (7.5)*** | 98.6 |
| M. quadriceps femoris | 0.073 (0.004) | -37.8 (12.9)** | 94.9 |

[1] * ($P<0.05$), ** ($P<0.01$), *** ($P<0.001$)

The chemical composition (water, lipid, ash, protein) of the carcass tissue components (muscle, IM fat, SQ fat, bone) and 4 individual muscles (SS, LD, SM, GB) were analysed with respect to total component or muscle weight and season (Table 4.31). The LD and SM both contained less water ($P\leq0.001$) but more protein ($P\leq0.001$) during the rut. The SS and GB were also contained more protein ($P<0.05$) at that time but there was no effect on muscle water. The SS and GB muscles also had less lipid ($P<0.05$) during the rut. For all muscles there was no effect of season on the ash content.

The total side muscle showed a similar trend with season as did the individual muscles with regard to muscle water and protein. That is less water ($P\leq0.01$) and more protein ($P\leq0.001$) during the rut. However there was a greater ash content in the total side muscle during the rut ($P\leq0.01$).

**Table 4.31.** Coefficients for the 'season' covariate ($b_2$) in the chemical composition of carcass tissues, individual muscles and total side carcass analyses when paired with appropriate independent variables ($b_1$). $x_2$ equals 1 for rut and 0 for non-rut.

| Dependent variable (y) | Independent variable ($x_1$) | Regression coefficients $b_1$ | | $b_2$[1] | | $r^2$ |
|---|---|---|---|---|---|---|
| Side protein | side weight | 0.189 | (0.004) | 86.0 | (21.2)*** | 98.9 |
| Muscle - water | side muscle wgt | 0.730 | (0.005) | −57.3 | (16.4)** | 99.9 |
| - ash | side muscle wgt | 0.0113 | (0.0006) | 5.97 | (1.92)** | 94.5 |
| - protein | side muscle wgt | 0.234 | (0.004) | 66.5 | (12.0)*** | 99.5 |
| IM fat - ash | side IM fat wgt | 0.0047 | (0.0006) | 6.85 | (0.26)** | 77.6 |
| Bone - water | side bone wgt | 0.22 | (0.04) | −44.6 | (16.4)* | 75.1 |
| - lipid | side bone wgt | 0.15 | (0.02) | 22.3 | (7.8) ** | 78.2 |
| SS - lipid | SS wgt | 0.015 | (0.001) | −0.17 | (0.06)* | 87.0 |
| - protein | SS wgt | 0.222 | (0.004) | 0.43 | (0.18)* | 99.4 |
| LD - water | LD wgt | 0.736 | (0.005) | − 6.8 | (1.8)*** | 99.9 |
| - protein | LD wgt | 0.240 | (0.005) | 7.0 | (1.7)*** | 99.1 |
| SM - water | SM wgt | 0.744 | (0.005) | − 7.2 | (1.2)*** | 99.9 |
| - protein | SM wgt | 0.234 | (0.005) | 7.15 | (1.2)*** | 99.1 |
| GB - lipid | GB wgt | 0.015 | (0.002) | −1.35 | (0.53)* | 81.7 |
| - protein | GB wgt | 0.266 | (0.004) | 3.29 | (1.17)* | 99.4 |

[1] *(P<0.05), ** (P<0.01), *** (P<0.001)

There was no effect of season on the chemical composition of the SQ fat. For the IM fat the only effect of season was an increase in ash.

The effect of season on the chemical composition of bone was to decrease the weight of water (P<0.05) and increase the weight of lipid (P<0.01) of the M17 group relative to animals of similar bone weight slaughtered in the nonrut period.

When all the carcass components were combined the apparent effect of season on the chemical composition of the carcass side was an

increase in the weight of protein of M17 animals relative to animals of similar carcass weight slaughtered in the nonrut period (Table 4.31).

## 4.8 MEAT QUALITY

### 4.8.1 General

In considering changes in meat quality with carcass weight and age the differences in the slaughter procedures between groups M13 and M25, and group M17 become very relevant. For this reason the analysis of the effect of carcass weight on meat quality has been conducted by using data from groups M13 and M25 only, while the effect of slaughter procedure and/or season of the year on meat quality has been assessed by comparing groups M13 and M25 pooled versus group M17.

Unfortunately any effects of slaughter procedure (commercial DSP vs shot in paddock) and season of the year (prerut vs rut) on meat quality are confounded in this study as the M17 animals in the rut were also the group which were shot in the paddock.

The group means for the meat quality measurements of colour (reflectance); pH, tenderness (W-B shear value) and WHC for the m. longissimus (LD) and m. semimembranosus (SM) are presented in Table 4.32. The reflectance values at 630 nm were greatest for both muscles for group M17 ($P<0.001$). No significant difference in R630 existed between groups M13 and M25 for either LD or SM. At R580 a similar trend existed. Group M17 had the greatest reflectance values for both muscles ($P<0.001$). However, for the LD, group M13 had a greater reflectance value than group M25 ($P<0.05$). No difference existed between R580 values for SM from groups M13 and M25.

**Table 4.32.** Means of meat quality characteristics of m. longissimus (LD) and m. semimembranosus (SM) for the three groups. [Mean values (SE)]

| | | Group | | | | Significance of difference[1] | Significance of difference[1] | |
|---|---|---|---|---|---|---|---|---|
| | | M13 | M17 | M25 | SED | | M13+M25vsM17 | M13vsM25 |
| Reflectance values | | | | | | | | |
| R630 | LD | 13.9 (0.6) | 22.5 (2.0) | 12.4 (1.7) | 1.273 | *** | *** | NS |
| | SM | 13.9 (0.5) | 21.8 (0.6) | 12.5 (1.0) | 2.24 | *** | *** | NS |
| R580 | LD | 4.1 (0.3) | 6.6 (0.8) | 3.1 (0.3) | 0.46 | *** | N/A[4] | * |
| | SM | 4.2 (0.4) | 5.6 (0.5) | 3.6 (0.3) | 0.36 | ** | *** | NS |
| R630-R580[2] | LD | 9.9 (0.5) | 15.9 (1.7) | 9.4 (0.6) | 1.6 | *** | *** | NS |
| | SM | 9.7 (0.5) | 16.2 (0.5) | 8.9 (0.7) | 0.8 | *** | *** | NS |
| Ultimate pH[3] | | | | | | | | |
| | LD | 5.60 (0.02) | 5.55 (0.01) | 5.54 (0.02) | 0.03 | * | N/A | * |
| | SM | 5.70 (0.04) | 5.64 (0.04) | 5.64 (0.02) | 0.05 | NS | NS | NS |
| Warner-Bratzler shear value (kg)[3] | | | | | | | | |
| | LD | 3.95 (0.26) | 3.34 (0.25) | 3.90 (0.35) | 0.41 | NS | NS | NS |
| | SM | 4.13 (0.15) | 4.92 (0.35) | 5.00 (0.28) | 0.39 | NS | N/A | * |
| Water-holding capacity | | | | | | | | |
| Expressible juice ($cm^2/g$)[2] (WHC 1.) | | | | | | | | |
| | LD | 14.69 (1.01) | 18.26 (0.66) | 14.22 (0.77) | 1.17 | ** | *** | NS |
| | SM | 16.18 (1.80) | 17.15 (0.43) | 13.80 (0.23) | 1.52 | NS | NS | NS |
| Expressible juice index[2] (WHC 2.) | | | | | | | | |
| | LD | 1.28 (0.10) | 1.86 (0.12) | 1.23 (0.13) | 0.17 | ** | *** | NS |
| | SM | 1.48 (0.16) | 1.63 (0.08) | 1.18 (0.03) | 0.15 | * | * | NS |

[1] *P<0.05; **P<0.01; ***P<0.001

[2] No significant differences between muscles

[3] Muscles significantly different (P<0.001)

[4] See text

These results suggest that group M17 had greater amounts of both the $MbO_2$ and MetMb forms of the pigment. However the method used could not discriminate if there were also group differences in total pigment concentration. From the difference, R630-R580, group M17 had the greatest proportion of pigment in the $MbO_2$ form ($P<0.001$), while the differences were not significant between groups M13 and M25. These measurements were supported by the observation that muscle tissue from group M17 animals was a bright red colour while that from group M13 and M25 animals was a dark red/purple colour.

No difference existed between the muscles in reflectance values or the difference, R630-R580.

The ultimate pH values showed a similar trend between the groups for both muscles, although the pH values were lower for the LD muscle ($P<0.001$) by approximately 0.1 pH unit. For the LD the pH value for group M13 was higher than that for groups M17 and M25 ($P<0.05$), but groups M17 and M25 did not differ significantly in terms of pH. For the SM the differences between group pH values were not significant.

From the WB shear values the LD was found to be more tender than the SM ($P<0.001$). There were no significant differences between age groups in tenderness of the LD despite group M17 having a lower W-B shear value. For the SM, group M13 had the lowest W-B shear value, being more tender than group M25 ($P<0.05$).

Neither the M13 nor the M25 groups differed significantly from group M17.

Two different calculation methods, based on the filter paper press technique, were used to determine the water holding capacity (WHC) of the LD and SM.

Both methods, the expressible juice ($cm^2/g$) (WHC 1.) and the expressible juice index (WHC 2.) (see Section 3.5.4) gave similar trends in WHC across the groups. (A decrease in WHC being associated with increased amounts of expressible water.) There were no differences in WHC between the LD and SM. Group M25 had the greatest WHC in both muscle groups, followed closely by group M13. Group M17 had a much lower WHC. The WHC of the LD was not significantly different between groups M13 and M25, but group M17 had a significantly lower WHC than both groups M13 and M25 ($P<0.01$). For the SM group M25 had a significantly greater WHC than group M17 ($P\leq0.05$) but was not significantly different from group M13. Also groups M13 and M17 did not differ significantly with respect to the WHC of the SM.

### 4.8.2 Slaughter Treatment/Season of Slaughter Analysis

For the measures of meat quality where the means for groups M13 and M25 did not differ significantly, meaning that there was no effect of age/carcass weight on these meat quality characteristics, the effect of slaughter treatment/season of slaughter could be investigated. This was so for all variables with the exception of the LD R580 and ultimate pH, and the SM W-B shear value. A significant effect of slaughter treatment/season of slaughter on meat quality was found for all other colour measurements, LD WHC 1., LD WHC2, ($P<0.001$) and SM WHC 2. ($P<0.05$). No effect of slaughter treatment/season of slaughter on meat quality was found for SM ultimate pH, LD W-B shear value, and the SM WHC 1. (Table 4.32).

Examples are examined individually where there was an effect of age/carcass weight on meat quality. For the LD, the amount of MetMb (R580) decreased with increasing age/carcass weight (M13 vs M25). There was however obviously an effect of slaughter treatment/season of slaughter which increased the amount of MetMb beyond the range of even group M13 values. Ultimate pH for the LD decreased with increasing age/carcass weight (M13 vs M25) with the value for group M17 falling between that of groups M13 and M25. This suggests that slaughter treatment/season of slaughter had no effect on LD ultimate pH.

The SM W-B shear value increased with increasing age/carcass weight (M13 vs M25) with the value for group M17 falling between that of groups M13 and M25. This suggests that slaughter treatment/season of slaughter had no effect on SM tenderness.

### 4.8.3 Relationships Amongst Measurements of Meat Quality

In Table 4.33 the simple correlation coefficients between the pooled group measurements of meat quality are presented.

For the LD, WHC 1. and WHC 2. were significantly correlated with muscle colour (R630-R580) ($P<0.001$). That is, a decrease in the WHC of the muscle was associated with an increase in the proportion of $MbO_2$ in the muscle.

WHC 1. and WHC 2. were also significantly correlated ($P<0.001$). Other characteristics did not appear to be related to each other. For the SM, WHC did not appear to be strongly correlated with muscle colour ($P<0.05$) and the correlation between WHC 1. and WHC 2. was lower than for the LD, although still significant ($P<0.001$). As with LD no other characteristics were significantly correlated.

**Table 4.33.** Simple correlations between measurements of meat quality on the mm longissimus and semimembranosus pooled between age groups.[1]

| | Ultimate pH | W-B shear value | WHC 1. | WHC 2. |
|---|---|---|---|---|
| M. longissimus | | | | |
| R630-R580 | -0.127 | -0.141 | 0.634*** | 0.655*** |
| Ultimate pH | | -0.172 | -0.333 | -0.257 |
| W-B shear value | | | -0.116 | -0.079 |
| WHC 1. | | | | -0.928*** |
| M. semimembranosus | | | | |
| R630-R580 | -0.118 | 0.317 | 0.320 | 0.408* |
| Ultimate pH | | 0.088 | -0.032 | -0.263 |
| W-B shear value | | | 0.008 | -0.028 |
| WHC 1. | | | | 0.623*** |

[1]* $P \leq 0.05$
*** $P \leq 0.001$

### 4.8.4 Further Subjective Observations of Meat Quality

Observations on carcass bruising and the incidence of ecchymosis were made on the intact carcasses and also at dissection. For the animals slaughtered in the Deer Slaughter Premises (DSP) bruising on the carcass was common but not severe. Small contusions were present on most animals on the point of the hip, shoulder and flank. At dissection it was noted that 3 animals had received more severe internal bruises in the neck region. Bruising was absent in the animals shot in the paddock.

Ecchymosis was present in the diaphragm muscles of most animals slaughtered through the DSP. This was seen to also be present in the

mm. semitendinosus, gluteobiceps, quadriceps femoris and less commonly in the m. longissimus for a lesser number of animals at dissection.

Ecchymosis was not observed on the intact carcasses of the animals shot in the paddock but was found to be present in at least one animal for the mm. semitendinosus and gluteobiceps.

## 4.9 PREDICTION OF PHYSICAL CARCASS COMPOSITION

### 4.9.1 Carcass Component Weights as Predictors

The usefulness of a number of variables as predictors of the weight of carcass muscle, fat and bone was evaluated using simple and multiple regression techniques. The predictor variables were grouped on the basis of their ease of measurement and likely economic cost of determination.

Carcass weight is the first variable measured in commercial deer slaughter premises and is used to determine producer payout. The next group of variables considered included kidney fat, kidney organ weight and cannon bone measurements. The kidney fat and kidney organs are normally removed from the carcass at joining. The cannon bones (metacarpals) are removed with the lower leg prior to skinning and are a waste component available for measurement. The eye muscle area and fat depth measurement 'C' were the next group of measurements to be considered. These require that the saddle be cut in the 12th-13th rib area, thus destroying the traditional form of the saddle cut. However, as further processing of this cut is now becoming popular these measurements are more likely to become viable.

Finally measurements on the neck and shoulder cuts were considered. These cuts have traditionally been boned out in

preparation for wholesale trade. This makes measurement of the tissue components of these cuts possible either on a commercial boning out basis or by laboratory dissection, without destruction of the saleable product. Where the neck was concerned, because the bones are difficult to clean and separation of the neck fat depot is difficult it was decided to examine the value of the weight of two neck muscles - the m. splenius and m. semispinalis - in predicting carcass composition. For the shoulder cut the tissue components plus individual bone weights were evaluated.

The predictive value of carcass measurements were not related independently to carcass composition but were evaluated in addition to carcass weight. However simple correlations between the individual predictors and carcass components are given in Table 4.34. These show that in the case of carcass fat, fat depth 'C' may be a slightly better predictor than carcass weight and humerus weight may be slightly better for total bone weight but carcass weight is clearly not far behind and is the most consistent predictor of all components.

**Table 4.34.** Simple correlation coefficients between predictor variables and carcass muscle, fat and bone weight.

| | Carcass Muscle | Carcass Fat | Carcass Bone |
|---|---|---|---|
| Carcass weight | 0.99 | 0.90 | 0.89 |
| Kidney fat | 0.62 | 0.85 | 0.46 |
| Kidney organ | 0.73 | 0.56 | 0.75 |
| Cannon weight | 0.64 | 0.55 | 0.57 |
| Cannon length | 0.55 | 0.46 | 0.53 |
| Cannon circumference | 0.27 | 0.38 | 0.11 |
| Eye muscle area | 0.80 | 0.71 | 0.76 |
| Fat depth 'C' | 0.87 | 0.94 | 0.81 |
| Neck | | | |
| M. splenius | 0.91 | 0.81 | 0.81 |
| M. semispinalis | 0.85 | 0.80 | 0.77 |
| Shoulder | | | |
| Muscle | 0.96 | 0.83 | 0.90 |
| Subcutaneous fat | 0.68 | 0.84 | 0.48 |
| Intermuscular fat | 0.71 | 0.80 | 0.77 |
| Total fat | 0.79 | 0.93 | 0.73 |
| Bone | 0.97 | 0.82 | 0.92 |
| Humerus weight | 0.97 | 0.83 | 0.93 |
| Humerus length | 0.87 | 0.79 | 0.87 |
| Radius + ulna | 0.97 | 0.82 | 0.91 |
| Scapula | 0.89 | 0.76 | 0.84 |

Carcass weight alone accounted for 97%, 81% and 80% of the total variation in the weight of carcass muscle, fat and bone, respectively (Table 4.35).

In the prediction of carcass muscle none of the variables in the first two groups of additional variables considered added to the value of carcass weight in explaining variation in carcass muscle weight. Only radius plus ulna weight added significantly to carcass weight in

explaining variation in carcass muscle weight and then only by a further 0.8%.

In the prediction of carcass fat the addition of kidney fat and fat depth 'C' and total shoulder fat accounted for a further 11.2%, 10.3% and 10.9% of the variation in carcass fat weight, respectively. Shoulder subcutaneous fat and intermuscular fat accounted for smaller significant percentages of the variation in carcass fat weight, as did humerus weight and total bone weight in the shoulder.

The measurement adding the most to carcass weight in explaining the variation in carcass bone weight was the weight of the humerus (6.8%). Radius plus ulna weight and shoulder subcutaneous and intermuscular fat weight also appeared to aid prediction of total carcass bone.

### 4.9.2 Carcass Linear Measurements as Predictors

Carcass linear measurements on groups M13 and M25 were also examined for usefulness as predictors of carcass muscle fat and bone weight when added to carcass weight itself. Only one linear measurement, WTH, the width of the carcass at the narrowest point behind the shoulders was of use. It accounted for a further 9.7% of the variation in carcass fat weight ($R^2$ = 94.3, $P \leq 0.001$, RSD = 364 g). Carcass length (LB) narrowly missed significance in accounting for further variation in carcass muscle weight and carcass bone weight ($R^2$ = 98.5, RSD = 484 g; $R^2$ = 85.3, RSD = 208 g respectively).

**Table 4.35.** Percentage variation ($R^2$) in carcass composition accounted for by carcass weight on its own and the increase when paired with various carcass side measurements in multiple regression equations.

| | Weight carcass muscle | | | Weight carcass fat | | | Weight carcass bone | | |
|---|---|---|---|---|---|---|---|---|---|
| | $r^2$ | Significance | RSD (g) | $r^2$ | Significance | RSD (g) | $r^2$ | Significance | RSD (g) |
| Carcass weight | 97.3 | *** | 522 | 81.3 | *** | 525 | 79.5 | *** | 209 |
| Additional variate | | | | | | | | | |
| Kidney fat | 0.3 | NS | 507 | 11.2 | *** | 341 | 3.4 | NS | 196 |
| Kidney organ | 0.1 | NS | 524 | 1.7 | NS | 513 | 2.5 | NS | 201 |
| Cannon weight | 0.0 | NS | 535 | 0.3 | NS | 534 | 0.1 | NS | 213 |
| Cannon length | 0.0 | NS | 534 | 0.2 | NS | 535 | 0.2 | NS | 213 |
| Cannon circumference | 0.2 | NS | 514 | 1.1 | NS | 522 | 3.2 | NS | 197 |
| Eye muscle area | 0.1 | NS | 519 | 0.0 | NS | 538 | 0.8 | NS | 210 |
| Fat depth 'C' | 0.0 | NS | 530 | 10.3 | *** | 359 | 0.4 | NS | 212 |
| Neck | | | | | | | | | |
| M. splenius | 0.0 | NS | 535 | 0.2 | NS | 534 | 0.2 | NS | 213 |
| M. semispinalis | 0.1 | NS | 523 | 0.7 | NS | 528 | 0.2 | NS | 213 |
| Shoulder | | | | | | | | | |
| Muscle | 0.4 | NS | 494 | 0.8 | NS | 526 | 2.2 | NS | 202 |
| Subcutaneous fat | 0.2 | NS | 511 | 7.4 | ** | 417 | 5.5 | ** | 183 |
| Intermuscular fat | 0.0 | NS | 534 | 4.7 | * | 464 | 3.6 | * | 194 |
| Total fat | 0.1 | NS | 528 | 10.9 | *** | 348 | 0.1 | NS | 214 |
| Bone | 0.1 | NS | 522 | 5.9 | * | 461 | 4.3 | * | 190 |
| Humerus weight | 0.2 | NS | 513 | 3.3 | * | 488 | 6.8 | ** | 175 |
| Humerus length | 0.0 | NS | 532 | 0.0 | NS | 538 | 3.4 | NS | 196 |
| Radius + ulna | 0.8 | ** | 452 | 3.0 | NS | 492 | 3.7 | * | 194 |
| Scapula | 0.0 | NS | 529 | 2.5 | NS | 501 | 0.4 | NS | 212 |

# Chapter 5

# DISCUSSION

## 5.1 INTRODUCTION

A major purpose of this study was to provide information on carcass weight, composition and quality of venison from farmed male fallow deer slaughtered at different ages. This information is required to allow producers to make decisions on the best age for slaughter.

Male fallow deer (bucks) appear to be close to mature weight by two years of age (Asher & Gregson, 1983). Bucks are commonly slaughtered at either one or two years of age. In addition the main market requires a chilled product and farmers are being encouraged to retain yearling animals for slaughter in their second winter to ensure continuity of supply. Also, in red deer the carcass composition of the mature stag undergoes marked changes through the autumn rut period (Tan & Fennessy, 1981) resulting in much lower percentage fat levels in the carcass post-rut than at other times of the year. It was therefore desirable to know if such changes occurred in immature fallow bucks during their second winter.

In this chapter results of the study are discussed in relation to the issues presented above. In addition, differences in carcass quality between the M17 slaughter group and the other slaughter groups are discussed. Comparisons of carcass composition, quality and proportion of high-priced cuts with those in other species are also made. Results relating to the growth pattern of individual muscles, bones, fat depots and non carcass components are discussed and compared with those in other species. Finally, practical implications of the

results of this study on the future of fallow venison for lean meat production, and on choice of slaughter age and weight are discussed.

## 5.2 DRESSING-OUT PERCENTAGE

The fallow bucks slaughtered in this study covered the range of carcass weights (23-39 kg) of bucks commonly slaughtered in New Zealand deer slaughter premises. However there was a problem in separating the effects of age and carcass weight on factors investigated because the two were quite highly confounded. There was a small overlap in weight between M13 and M17 animals but no overlap between either of these groups and the M25 group. From a practical viewpoint however, the results reflect the situation that occurs in the production system.

Irrespective of age there was a good linear fit between liveweight and carcass weight (see Fig. 4.1). Dressing-out percentage increased with increasing carcass weight as occurs in sheep, cattle and red deer (Kirton et al., 1972; Murray et al., 1974; Murray & Slezacek, 1976; Drew et al., 1978; Kay et al., 1981). Liveweight ranged from 41 to 66 kg. Dressing-out percentage increased from 58.6 to 61.8 over this liveweight range.

The above dressing-out percentages agree closely with the value of 61% reported by Trauttmansdorff (1982) for 54 kg liveweight fallow deer but they are higher than those generally reported for sheep, cattle and red deer (Drew et al., 1978; Kay et al., 1981; Kempster et al., 1982; Kirton et al., 1984). Common values for these species are 41% for lambs (Kirton et al., 1984), 48.5% for sheep

(Kempster et al., 1982), 54% for cattle (Kempster et al., 1982) and 50-57% for red deer (Drew et al., 1978; Kay et al., 1981).

In cattle higher dressing-out percentages have been associated with greater proportions of carcass fat (Seebeck & Tulloh, 1966) and heavier muscled carcasses (Kauffman et al., 1976). The fallow deer in this study had a low carcass fat percentage. The high dressing-out percentage for fallow deer appeared to be due to high proportions of carcass muscle when compared to other species.

### 5.2.1 Carcass Weight Loss on Cooling

Carcass weight or fatness was apparently not associated with the extent of carcass weight loss during cooling (e.g. Lawrie, 1979) but cooling losses varied considerably between the two slaughter practices. Groups M13 and M25 were subjected to mechanical convection cooling while still above ambient air temperature, and consequently experienced greater weight losses than group M17 carcasses which were hung at winter night air temperatures. However the two percent difference in weight retained by the M17 carcasses could not be accounted for in the form of greater dissection losses or higher carcass water content. The amount of expressible juice in M17 muscle tissue was noted to be the highest (see Section 4.8.1).

### 5.2.2 Growth of Non-Carcass Body Components

Since the dressing-out percentage (carcass weight) increased with respect to liveweight, the proportion of the non-carcass components must have decreased.

Components vital to the growth and survival of the animal usually exhibit early maturing characteristics; as did the lower legs, liver,

lungs, head and gut in this study and in others (Luitingh, 1962; Kirton et al. 1972; Geay, 1978; Butterfield et al., 1983c).

The legs are largely composed of bone in fallow deer and as with other ruminants (Berg and Butterfield, 1975) the lower limb bones are relatively well developed in length at birth (see Table 4.21).

The gut component in this study comprised the rumen, reticulum, omasum, abomasum, spleen, large and small intestines, and omental and mesenteric fat. Some components of the alimentary tract were actually classified as late maturing by Kirton et al. (1972). However their study included the immediate post-natal period of growth which explains their classification since components of the digestive tract undergo dramatic changes in size during this period.

The heart has been determined as an early maturing organ in studies with sheep and cattle (Kirton et al., 1972; Geay, 1978; Butterfield et al., 1983c). The average relative growth classification of the heart in this study could have been due to the observed deposition of fat around the heart with increasing body weight. The actual weight of fatty tissue on the heart was not recorded. The average maturing pattern of the hide is accounted for by increases in surface area and hide thickness as liveweight increases (Butterfield et al., 1983c).

The observations of Chapman and Chapman (1975) suggested that the male reproductive organs in fallow deer attain maximum weight just before the rut in the mature buck and the peak weight of the testes at the time of the rut is fairly constant in relation to the bodyweight of animals 3 years old and older. In this study full redevelopment of the sexual organs in the 2-year-old deer would have commenced.

These organs would also be undergoing gradual increases in weight in the yearling bucks prior to their first rut (Chapman & Chapman, 1975). This study suggested weight of reproductive organs per unit body weight was constant between 1- and 2-year-old bucks prior to the rut. The growth patterns of the non-carcass components of the fallow deer appear to largely conform to those found for other domestic ruminant species.

## 5.3 CARCASS DISSECTIBLE COMPONENTS

Trends in dissectible carcass composition in fallow deer appear similar to those found in other domestic ruminants (e.g. see Kempster et al., 1982). With increasing carcass weight the percentages of bone and muscle decreased from 14.3 to 12.3 and from 74.3 to 70.1, respectively, while the percentage of fat increased, from 7.8 to 12.3 (Table 4.4, Fig. 5.1a).

Compared to sheep and cattle at normal carcass weights (e.g. Berg & Butterfield, 1975; Kempster et al., 1982) the percentage carcass fat in M25 bucks was low, despite the percentage carcass fat increasing by 65% between M13 and M25 animals.

Of the three fat depots (subcutaneous, intermuscular and kidney), subcutaneous fat grew the fastest followed by intermuscular fat. However intermuscular fat was still the largest fat depot in the heaviest group of animals studied (52% of total fat). Broad and Davies (1980) and Fourie et al. (1970) found similar trends in the growth of subcutaneous fat relative to intermuscular fat in rams. In the rams, however the magnitude of the allometric growth coefficients relative to total carcass weight for subcutaneous, intermuscular and

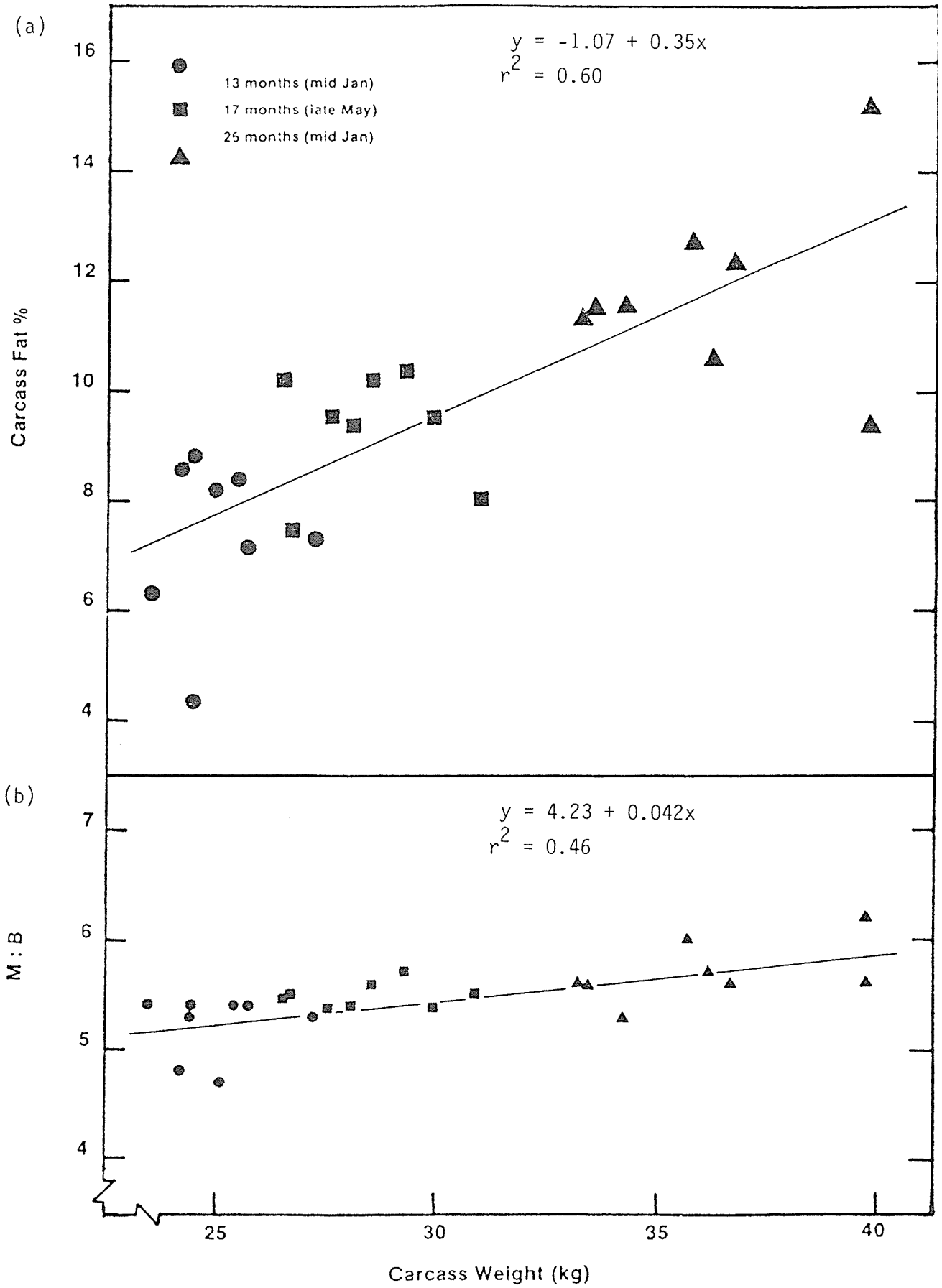


Figure 5.1. (a) The relationship between carcass fat percentage and carcass weight for male fallow deer.
(b) The relationship between muscle to bone ratio (M:B) and carcass weight for male fallow deer.

kidney fat were lower than those calculated here for the respective fat depots. Robelin (1978) studying bulls, calculated an allometric growth coefficient (b=1.48) for carcass fat tissue (subcutaneous, intermuscular and internal, excluding kidney) which was also well below the equivalent value of 2.21 (SE=0.24) obtained in this study. The higher allometric growth coefficients for fat depots in this study may in part be due to; first, the fact that the growth range studied in this experiment included just the latter stages of development towards maturity, as opposed to the above studies which included earlier stages of development as well. Secondly mature male deer have been shown to exhibit increased lipogenesis in late summer and autumn (Anderson, 1972) prior to breeding. If this began to occur in the M25 slaughter group it would have increased the allometric growth coefficient for the fat depots.

The magnitude of the allometric growth coefficient for total bone relative to carcass weight (b=0.62) was similar to that found by Robelin (1978) for bulls (b=0.66), but lower than those found by Fourie et al. (1970) for rams (b=0.71-0.77), and slightly higher than those found for wethers by Murray and Slezacek (1976) (b=0.43-0.67).

The percentage carcass muscle was higher than in other species at normal carcass weights (e.g. Kempster et al., 1982) but percentage muscle declined with increasing carcass weight as reported for other species (e.g. Berg & Butterfield, 1975). The allometric growth coefficient for muscle was also in general agreement with the published literature on sheep and cattle (e.g. Fourie et al., 1970) although both Robelin (1978) and Murray and Slezacek (1976) have reported values not differing significantly from one.

The data did not agree with recent data of Field (1985) for fallow bucks where muscle percent was reported to increase from 74 to 76% as age and carcass weight increased from 25 to 28 months and 26 to 31 kg respectively. Field suggested that his 'unexpected result' may have been due to a negative influence of plasma testosterone on fat deposition during autumn. However Drew (1985) suggested that lipogenesis increases in red deer over the late summer-autumn period.

The feature of carcass composition which contrasts most sharply with sheep and cattle at typical slaughter weights is the lower fat percentage. At a similar carcass weight of 30 kg, the Romney, Southdown and Southdown x Romney ram carcasses of Fourie et al. (1970) contained three times as much carcass fat but had a slightly higher muscle to bone ratio of 5.85. Lean sheep slaughtered in the United Kingdom are reported to contain only about 12% carcass fat but have very low muscle to bone ratios of about 2.9 (Kempster et al., 1982). Carcass fat percentage in Friesian bulls was also higher at 18% while the muscle to bone ratio was lower at 4.0 (Fisher et al., 1982).

The increase in muscle to bone ratio in this study (approximately 0.4 units/10 kg in carcass weight (see Fig. 5.1b) was much greater than that of 0.03 units reported in steers by Berg and Butterfield (1966). The magnitude of the increase in muscle to bone ratio with increasing carcass weight paralleled more closely that reported for entire male pigs (Walstra, 1980).

The generally greater muscle to bone ratios in fallow bucks than in sheep and cattle appeared to be the result of a higher percentage of carcass muscle, compared to sheep, (Callow, 1948) and both a higher percentage of muscle and lower percentage of bone, compared to cattle.

Despite apparently higher allometric growth coefficients for fat in fallow bucks than in bulls and rams, fallow buck carcasses appear to remain of desirable composition at weights closer to mature weight due to low absolute levels of carcass fat.

## 5.4 CARCASS CHEMICAL COMPONENTS

The changes in chemical composition with increasing carcass weight largely paralleled the changes in dissectible tissue composition. Muscle tissue consisted of 75% water and 22% protein and was consistent between M13 and M25 groups. The trends in carcass water and protein content, relative to carcass weight, both followed closely the trends in muscle growth as determined by allometric growth coefficients. Of significance though was the higher than expected percentage protein in the M17 group. This was accompanied by a correspondingly lower water percentage for this group. Lipid and ash percentages remained unaffected. The water to protein (W:P) ratio was found to decrease to a value of 2.96 compared to values of 3.09 and 3.02 for M13 and M25 animals, respectively. This trend in immature fallow bucks slaughtered during the rut is in contrast to the findings of Field (1985) for mature bucks where the carcass W:P was 2.73 in January (pre-rut) and 2.94 in April (during rut). It is also in contrast with the findings of Tan and Fennessy (1981) for red deer. They found entire animals had higher W:P ratios than castrates when slaughtered immediately pre-rut (mid March). Since castrates do not show the large fluctuations in body weight or visible changes in neck musculature in response to photoperiod this difference was most likely

to be due to photoperiodic-mediated hormone changes in the entires (Tan and Fennessy, 1981).

The lower water and higher protein percentages of the group M17 carcasses appeared to be largely due to the chemical composition of the muscle tissues which exhibited this trend. The W:P ratio for group M17 carcass muscle was 3.26 compared to 3.41 and 3.32 for groups M13 and M25 respectively. For the individual muscles the trend was similar with group M17 having water percentages lower than or similar to those of group M25 and generally higher protein percentages than both other groups. This resulted in W:P ratios ranging between 3.08 and 3.49 for the individual muscles in group M17, and 3.24 to 3.52 and 3.27 to 3.61 for groups M25 and M13 respectively. For bone the lower and higher percentages of water and protein respectively in M17 animals was not as apparent. In the subcutaneous and intermuscular fat depots no such trend was apparent in the chemical composition between age groups.

## 5.5 COMMERCIAL CARCASS CUTS

The effect of carcass weight on the proportion of the carcass in the primal cuts and the composition of these primal cuts is of commercial importance in making a decision on the desirability of different slaughter weights. Fallow venison has been marketed in the form of bone-in primal cuts (haunch and saddle) and boneless meat of two quality grades; A (neck and sometimes shoulder) and B (flank and other trim) (see Fig. 3.1). More recently exporters have been further processing the saddle and haunch into portion controlled pieces and smaller cuts more suitable for the wholesale restaurant trade.

The results of this study showed that as carcass weight increased the percentage of the carcass in the primal cuts decreased slightly by about 2.2%. This was due solely to a decrease in the proportion of the carcass in the haunch cut and agrees with data of Drew and Greer (1977) for red deer. The decrease was due to a decrease in the proportion of bone in the haunch relative to total carcass bone. Muscle growth in the haunch occurred at the same rate as total carcass muscle. Therefore this gives an increase in the M:B ratio in the haunch from 6.5 to 7.3 units, with increasing carcass weight from 25 to 36 kg.

In the saddle, muscle and bone components increased at similar rates to total carcass muscle and bone but fat increased at a slightly greater rate than in the rest of the carcass. This increase was predominantly in subcutaneous fat on the exterior of the cut. Generally, then, it appears that as carcass weight increases the muscle component of the primal cuts does not suffer.

Of the other commercial cuts the proportion of total carcass fat in the flank increased while that in the shoulder decreased as carcass weight increased. This was reflected in these cuts becoming a greater and lesser proportion, respectively, of the carcass with increasing carcass weight.

On a commercial basis these results imply that with increasing carcass weight the proportion of lower quality boneless 'B' will be increasing while the proportion of the better quality boneless 'A' will be decreasing relative to total boneless meat.

The proportion of carcass weight in each of the 5 commercial cuts was similar to that reported for red deer (Scandrett, 1982) but the

percentage of primal cuts (saddle and haunch) appeared to be greater in the fallow deer at an average over all slaughter groups of 54.9 percent. Trauttmansdorff (1982) reported similar high proportions of primal cuts in fallow deer of 56.3 percent for 15 month old bucks at 54.4 kg liveweight.

It is possible that the smaller more agile fallow deer has an increased proportion of its muscle weight concentrated around the spinal column as demonstrated by Berg and Butterfield (1975) for agile animals.

Comparisons on a commercial cut basis with sheep and cattle are complicated by the venison industry's unique jointing procedures. It is also worth noting that particularly in the case of the saddle and flank cuts anatomical boundaries for the division of cuts are not easily defined. In addition, small corrections had to be made at dissection time to some M17 cuts which were separated along slightly different lines to groups M13 and M25. For these reasons most interspecies comparative discussion is concentrated on the distribution of the weight of muscle groups, individual bones and fat depots.

## 5.6 RELATIVE MUSCLE GROWTH AND PROPORTIONS

The muscle weight distribution in fallow bucks changed little over the growth trajectory studied based on analysis of commercial cuts. It is likely that in fallow deer, as in cattle (Butterfield, 1965), the greatest relative muscle weight changes occur within the first few months of life and therefore were outside the range of the growth trajectory studied. However, some carcass cuts contained

muscles, which in cattle, have been reported to have both high and low growth impetus relative to total carcass muscle. Two possibilities existed in this study, despite the apparent lack of muscle weight redistribution when assessed on a commercial cut basis. First compensation between the growth of two muscles in one commercial cut may have occurred where the muscle groups were of similar weight. Alternatively individual muscles or muscle groups within a cut may have had a different growth pattern to the total cut muscle, but because they represented only a small proportion of the total they had no effect on the overall classification.

The allometric growth coefficients for a number of individual muscles illustrated the changes in muscle weight distribution that did occur within the carcass cuts (see Table 4.16).

The neck muscle m. splenius had a high growth impetus which is in agreement with other studies using entire (Jury et al., 1977; Brännäng, 1971) and castrate ruminants (Butterfield & Berg, 1966a). This muscle is responsible for the crest formation in the male. The m. semispinalis also had a higher growth impetus similar to that found by Brännäng (1971) in bulls but contrary to Butterfield and Berg (1966a) with steers (average) and Jury et al. (1977) with rams (low).

The large standard error associated with the AGC of the total muscle of the neck cut, which was probably due to inconsistencies in the splitting and separation of this cut, may have masked the trend towards a high relative growth impetus classification for the total neck muscle.

The m. longissimus in the saddle was found to have an average growth impetus as in Butterfield and Berg (1966a), and Brännäng

(1971), although Jury et al., (1977) reported that this muscle became a decreasing proportion of total side muscle with increasing carcass weight in entire rams. For the individual haunch muscles (mm. semitendinosus, semimembranosus, quadraceps femoris) there is little agreement between other studies (Butterfield & Berg, 1966a; Jury et al., 1977; Brännäng, 1971) regarding their growth impetus classifications, although generally the respective magnitudes of the allometric growth coefficients are similar to those found in this study.

The exception is the m. gluteobiceps, which in this study had a high growth impetus. In other studies this muscle had an average (Butterfield & Berg, 1966a) or low growth impetus (Jury et al., 1977; Brännäng, 1978). Butterfield and Berg (1966a) concluded that the growth of those muscles situated most closely to the skeleton had a low or a low-average growth impetus. This finding is supported in this study with the mm. quadraceps femoris and longissimus which had a low and an average growth impetus respectively, while the superficially situated m. gluteobiceps exhibited a high growth impetus.

Some degree of redistribution of weight between muscles in the haunch appeared to be occurring with growth, but is likely to be of little commercial significance.

Comparisons of complete muscle weight distribution of the fallow deer with those of other domestic ruminant species are difficult because complete muscle dissection was not undertaken in this study.

However, it appears that a greater proportion of the carcass muscle is found in the hind leg of the fallow buck (42%) compared with

bulls (Berg & Mukhoty, 1970) and rams (Jury et al., 1977) at approximately 33 and 31% respectively. There is also a suggestion that the entire fallow deer and sheep have similar proportions of muscle in the spinal region (Jury et al., 1977), which is approximately 4% more than that found in bulls (Berg & Mukhoty, 1970).

Between species comparisons of muscle distribution over the remainder of the carcass were not possible due to the cutting procedure used in this study. The fallow deer, like the white-tailed deer (Berg & Butterfield, 1975), appeared to have a higher proportion of its musculature located in the traditionally 'high priced' cuts of the hind leg and spinal regions than sheep and cattle. However, because of the animals small size foreleg cuts which are 'high priced' in beef carcasses are more difficult to exploit.

Comparisons of individual muscle weights as proportions of total carcass muscle may be made with other studies with deer, sheep and cattle as follows.

In fallow deer of similar carcass weights to the M13 animals in this study, Field (1985) found the m. splenius to be of a similar proportion of total muscle - approximately 0.30%. Averaging across all age groups in this study the m. splenius represented 0.38% of total carcass muscle, which was a similar proportion to that found in rams (Jury et al., 1977) but about half that found in steers (Charles & Johnson, 1976). The proportion of carcass muscle in the m. semispinalis (0.78%) was less than that found for both rams (1.23%; Jury et al., 1977) and steers (1.64%; Charles & Johnson, 1976).

The m. longissimus weight represented a similar proportion of the total musculature in this study (8.9%) as it did for 25 month old fallow bucks in Field (1985) at 9.3%. However in Field's 27 month old bucks the m. longissimuss represented only 7.6% of total muscle weight. In other species the m. longissimus has been reported to represent a slightly higher (9.7%) and significantly lower proportion (6.2%) of total muscle weight in rams (Jury et al., 1977) and bulls (Berg & Mukhoty, 1970) respectively.

Three of the four haunch muscles weighed individually were each a greater proportion of total muscle weight than the same muscles in rams (Jury et al., 1977) and steers (Charles & Johnson, 1976). The m. semitendinosus was the exception. It comprised a greater proportion of total muscle than in rams (1.82%; Jury et al., 1977) but lower than in steers (2.36 to 2.58%; Charles & Johnson, 1976). The comparison with entire cattle may however have favoured the bucks due to a greater proportion of muscle weight in the forequarter region of bulls than steers (Berg & Butterfield, 1975). In this study the four individually recorded haunch muscles represented 25% of the total carcass muscle weight. In rams (Jury et al., 1977) and steers (Charles & Johnson, 1976) this group represents 17.5 and 21% respectively of total carcass muscle weight. This supports the earlier contention that a greater proportion of carcass muscle occurs in the haunch of the fallow deer than sheep and cattle.

In summary, the results of this study conform to theories of Berg and Butterfield (1976) with the fallow buck having a greater proportion of total muscle weight in the hindquarter compared to rams and bulls. However more detailed work is required to apportion the

muscle weight in the other carcass regions more accurately - especially that of the neck and shoulder regions.

## 5.7 RELATIVE BONE GROWTH AND PROPORTIONS

Distribution of bone weight changed little over the carcass weight range in this study. Two individual carcass bones had a low growth impetus relative to total bone. These were the tibia plus tarsus and femur in the haunch. With the exception of the haunch cut the total bone of each of the carcass cuts had an average growth impetus. The femur, tibia and tarsus comprised by weight between 68 and 70 percent of the haunch-cut bone.

A number of observations in this study support the 'growth gradients' theory of Pàlsson and Vergés (1952).

In the thoracic limb the distally located metacarpal had a low growth impetus. Progressing up the limb there was a trend towards greater allometric growth coefficients for the individual bones, although they were not significantly different from one. A similar trend existed in the pelvic limb; the femur having a greater AGC than the tibia plus tarsus, although both had a low growth impetus. The average growth impetus classification of the remaining haunch bone, while in keeping with "waves of growth theory", needs further investigation owing to the relatively high standard error (see Table 4.20).

The growth rate in bone length relative to carcass length also conforms to Pàlsson and Vergés' (1952) observations. The AGC for the metacarpal is much smaller than those recorded for the humerus and femur although all are classified as having a low growth impetus. The

AGCs for the bone lengths relative to carcass length are also less than those for bone weights relative to total bone weight which suggests that mature length of these bones was reached earlier than the mature bone weights (see Tables 4.20 and 4.21).

The statement of Pàlsson and Vergés' (1952) that the thickening of bones takes place at later stages in growth could not be confirmed from this study as both metacarpal length and circumference had low growth impetus relative to carcass length.

That the ribs are relatively later maturing than the sternum, as found by Pàlsson and Vergés (1952), could not be investigated in this study owing to the method of cut separation. However it is interesting to note that the bone of the saddle, which comprised the thoracic and lumbar vertebrae, and the upper portion of the ribs, had a greater AGC than the bone of the flank, which comprised the lower portion of the ribs and the sternum. Bone distribution is important in fallow deer as at present the venison trade largely markets primal bone-in joints, with the exception of the neck and flank. In cattle it has been shown that most bones (or bone weights in different joints) grow at similar rates to total bone over the commercial slaughter weight range (Seebeck & Tulloh, 1968; Seebeck, 1973). The leg bones have differed to the greatest degree, growing more slowly than total bone.

For these fallow deer the only detectable change in bone weight distribution over the carcass weight range considered was in the haunch cut. Here bone growth was relatively slower than that in the remainder of the carcass. Combined with the average growth impetuses given to muscle and fat in this cut this produced a drop in the bone

weight percentage of this cut from 12.6 to 10.9% of haunch weight over the carcass weight range of 25 to 36 kg.

## 5.8 RELATIVE FAT GROWTH AND PROPORTIONS

Total side fat distribution changed with increasing carcass weight. Fat in the saddle and flank became an increasing proportion of total side fat, while that in the neck, shoulder and haunch became a decreasing proportion. Differential fat growth reported in a number of other studies with cattle (Seebeck & Tulloh, 1968; Kempster et al., 1976a; Berg et al., 1978c; Jones et al., 1980b) generally followed a similar pattern. That is, growth impetus for total fat in a cut was lowest in the limbs, neck and rump regions, increasing to a high impetus in the mid-back and flank regions.

Despite differential trends in fat depot growth, the cuts changed little in their fat content ranking. The flank remained the fattest cut being 15 and 26% fat for the M13 and M25 groups, respectively, while the neck remained the leanest cut with 4.5 and 5.6% fat for groups M13 and M25 respectively. The shoulder was the second fattest cut (7.7%) followed by the saddle (6.9%) for M13 animals but at M25 the order was reversed, the saddle having 11.7% and the shoulder 9.8% fat. The haunch remained the second leanest cut at 5.7 and 9.1% fat. Of practical significance is that the boned-out flank cut in M25 animals with 29% fat would result in a low quality boneless product compared to that in M13 animals. It may however be possible to trim approximately half this prior to boning out since 14% of this boneless tissue was subcutaneous fat.

Apart from the flank cut the proportion of fat in the commercial cuts (4.5-6.9% for M13, 5.6-11.7% for M25) was much lower than that found generally in sheep (Barnicoat & Shorland, 1952).

In general agreement with sheep and cattle subcutaneous (SQ) fat was a faster growing depot than intermuscular (IM) fat over normal slaughter-weight ranges (Kempster et al., 1976a; Kempster, 1981). The growth of SQ fat relative to total fat (AGC=1.32) appeared to be proportionately greater than that in bulls (AGC=1.06±0.03; Jones et al., 1980a) and lesser than that for sheep (AGC=1.81±0.01; Kempster, 1981). The IM fat grew at a similar proportionate rate to that in sheep (AGC=0.79±0.01; Kempster, 1981).

The ratio of SQ to IM fat (SQ:IM) increased from 0.56 at M13 to 0.93 at M25. Similar values have been estimated for rams (Kirton et al., 1972) at carcass weight ranges 10 to 30 kg and carcass fat percentages between 10 and 13.6% (subcutaneous and intermuscular). In bulls the ratios appear to be lower ranging between 0.33 and 0.79 over commercial slaughter-weight ranges (Fisher et al., 1982).

Higher SQ:IM ratios at greater carcass weights and fatness levels could be a desirable characteristic in a meat producing animal because subcutaneous fat can be trimmed more easily than intermuscular fat and is therefore preferable in carcasses containing fat in excess of consumer requirements. The 25-month-old fallow bucks of Field (1985) were of similar carcass weight and had a similar SQ:IM ratio of 0.57 to the M13 animals in this study. The interesting difference between the two groups of animals was that despite them also being similar in terms of dissectible carcass fat (8.4% vs 7.3%, respectively) Field's bucks were much fatter in terms of chemical

fatness (8.6% vs 6.8%, respectively). This could be attributed to greater percentage levels of lipid in Field's muscle (1.9 vs 1.4%), bone (14 vs 12%) and, SQ and IM fat depots (68 vs 45% and 48 vs 44%, respectively). The percentage chemical composition of Field's M25 animals was closer to those of the M25 animals in this study which were approximately 10 kg heavier in carcass weight and had 3% more dissectible carcass fat. Inferring across these experiments it appears that there is a 'maturity' factor as well as carcass weight involved in determining the percentage lipid in each of the tissues above.

Irrespective of animal age or carcass weight the lipid content of dissected fat tissues in lamb and mutton carcasses is much higher than the values reported here, varying from 66.4 to 85.8% in Barnicoat and Shorland's (1952) study. The low contents of chemical fat in dissected adipose tissues is to be expected when overall level of fatness is low (Broad & Davies, 1980).

### 5.8.1 Back-fat Depth 'C'

Fat depth 'C' is a measure of the depth of subcutaneous fat over the thickest part of the m. longissimus in the 12th-13th rib area.

While 'C' was positively correlated with carcass subcutaneous (SQ) fat, total fat and carcass weight, this measurement lacked sufficient sensitivity to detect differences in carcass fatness between M13 and M17 animals despite saddle SQ fat increasing significantly between these groups. A possible explanation for this is that the extent of SQ fat cover over the saddle was increasing, but not the depth. Also, as the fat depths were minimal (1.3-1.4 mm) in

groups M13 and M17 the method of measurement may not have sufficient precision. Relative to total side SQ fat, total side fat and side weight the subcutaneous fat of the saddle was also found to increase more rapidly giving AGC's of 1.26±0.09, 1.67±0.13 and 3.25±0.56, respectively. These AGC's are of similar magnitude to those calculated for the fat depth measurement 'C' in Table 4.28. This meant that fat depth 'C' increased at a greater proportional rate than total side SQ fat or total side fat despite the fact that 'C' is a linear measurement as opposed to a gravimetric measurement.[1]

## 5.9 SEASONAL EFFECTS ON CARCASS COMPOSITION

Carcass composition and chemical differences between the M17 group and the other groups were investigated for the possibility of a seasonal effect as reported by Tan and Fennessy (1981). Although there was no effect on the proportions of fat, muscle and bone in the carcasses of M17 bucks there were significantly reduced proportions of the four individually weighed haunch muscles and an increase in one of the two neck muscles (m. splenius).

Tan and Fennessy (1981) also recorded enlargement of the muscles of the neck region in mature entire red stags about the mating season and a return to their original size after the rut. The dissected muscle in 27-month-old red deer stags was by proportion 7% heavier in the forequarter and 7% lighter in the hindquarter than their contemporary castrates in that study. Individual forequarter muscles which were proportionately heavier in the entires, included the mm. splenius (SP) and semispinalis (SS). Hindquarter muscles which were proportionately lighter, included the mm. semimembranosus (SM),

[1]See Section 3.6

gluteobiceps (GB) and quadraceps femoris (QF). However they found no difference in the proportions of the m. semitendinosus (ST).

Field (1985) with mature fallow bucks slaughtered in January or April found the SP increased from 0.29 to 0.61% of carcass side muscle weight while the ST and SM decreased from 2.0 to 1.7% and 6.6 to 5.8% respectively.

The above trends, while in agreement with this study, appear to be of greater magnitude and can probably be explained by the greater degree of sexual maturity in 2-year-old compared to 1-year-old bucks and hence their greater response to the seasonal stimuli.

While the proportions of fat, muscle and bone did not change with season there was significantly more protein in the carcasses of group M17 animals as previously discussed (Section 5.4). This effect was due solely to a decreased water to protein ratio in the muscle component of the carcass. This contrasts with other studies where trends have been towards decreased protein, increased water and lipid, and decreased ash percentages for deer slaughtered in autumn (Field, 1985) or under the influence of short day lighting (Abbott et al., 1984). However, only some M17 muscles (LD and SM) had less water, others (SS and GB) had less lipid (see Table 4.18).

Much of the data from the seasonal analysis section appears contradictory to that found in other studies. It is possible that the seasonal effects on the chemical composition of the carcass was masked by an overriding effect of slaughter treatment. The method and conditions about slaughter were very different for the M17 group. Any loss of water from the carcass components prior to measurement would

be reflected in lower water to protein ratios. These, and carcass quality issues are discussed in the next section.

## 5.10 MEAT QUALITY

### 5.10.1 Effect of Season/Slaughter Practice on Meat Quality

Differences in meat quality characteristics that would affect consumer acceptance and explanations that could account for the lower proportion of water in the muscle tissue of the M17 animals were sought.

No obvious effect of season or slaughter treatment was found for the meat quality characteristics of ultimate pH ($pH_u$) or W-B shear value (tenderness). However muscle from M17 animals had a brighter red colour and a lower water-holding capacity (WHC) compared to M13 and M25 muscle (see Table 4.32) These latter measurements were the only ones to be significantly correlated. The highest WHC was associated with the darkest colour. One of the most important factors influencing the WHC of muscle is the rate and extent of pH fall during post mortem glycolysis. Fast rates of fall and low $pH_u$ values are associated with decreased WHC (Lawrie, 1979). In this study there were no differences between slaughter treatment $pH_u$ values. However, M17 animals were dressed and hung at higher temperatures (4-12 °C) than the other groups which, approximately 30 minutes following slaughter, were railed into a chiller (~ 4 °C). The higher environmental temperatures may have increased the rate of post mortem glycolysis in the M17 carcasses (Lawrie, 1979) and hence the rate of pH fall. However, higher rates of pH fall in pork usually result in

muscle which is pale in colour. This was not observed in the M17 tissue.

In addition to the above, the slower freezing of the M17 carcass could have caused ice crystal damage to the muscle proteins and subsequently a decrease in WHC. Fast freezing, as with the blast frozen M13 and M25 carcasses, is associated with higher WHC and less drip loss on thawing, but may have also caused darkening of the muscle tissue by pre-empting post mortem glycolysis (Lawrie, 1979).

The implication from the above is that the muscle tissue from the M17 animals was of 'PSE' character. However its physical appearance (i.e. its bright colour rather than pale) was not indicative of this condition as described in pork. Similarly, despite the dark colour of the M13 and M25 meat which could have been induced by these animals exposure to greater preslaughter stress (Lawrie, 1979), $pH_u$ values did not coincide with the DFD condition.

The differences between M13 and M25, and M17 therefore remain largely unexplained. The lower WHC, lower percentage moisture and higher percentage protein of the M17 muscle tissue seem likely to be indicative of the same condition. Whether this was due to an effect of season of slaughter or the method of slaughter cannot be ascertained.

### 5.10.2 Effect of Animal Age/Carcass Weight on Meat Quality

There was no significant effect of increasing age/carcass weight on SM colour or $pH_u$ although the same general trend existed for the LD, with darker colour and a significantly lower $pH_u$ at 25 months of age.

The SM was, however, significantly less tender in the M25 group. This may be associated with the higher collagen and elastin content of this muscle relative to the LD, and the extensive crosslinking which occurs with increasing age in these components (Lawrie, 1979).

Water-holding capacity increased from group M13 to M25 but no significant effects of age/carcass weight showed up for either muscle. It can be concluded that the effects of increasing age/carcass weight on the eating quality characteristics measured in this study are minimal for fallow venison.

### 5.10.3 Correlation Between Meat Quality Measurements

The relationships amongst the measurements of meat quality were very poor, with only muscle colour and WHC being significantly correlated (see Table 4.33). In controlled experiments with sheep, cattle and pigs, a darkening of muscle colour and an increase in WHC is normally associated with an increase in $pH_u$ and increased tenderness. This apparent inconsistency is discussed in section 5.10.1.

### 5.10.4 Comparative Aspects of Meat Quality

The $pH_u$ of typical mammalian muscle is in the range of 5.4 to 5.5 (Lawrie, 1979). In studies with red deer the pH values of the LD have range from 5.57 for stags shot in the wild to 6.23 for stags held overnight prior to slaughter(Kay et al., 1981). Values for the SM have ranged from 5.6 to 6.6 under differing preslaughter stress regimes (MacDougall et al., 1979). At higher muscle $pH_u$ values the meat from these deer has been classified as dark cutting (MacDougall

et al., 1979) but no indication has been given of the lower pH limit for this classification.

In this study, apparent differences in preslaughter stress levels perhaps produced the changes in muscle colour and WHC, but did not show up in $pH_u$ values. The significantly greater $pH_u$ of the SM compared to the LD is a characteristic also observed in other species (Lawrie, 1979). W-B shear values of 3.30 to 3.95 kg for the LD and 4.1 to 4.0 kg for the SM were low by comparison to other species. Values in the range of 5-20 kg for cattle LD and 3-6 kg in lamb SM have been recorded using the same methods and equipment (Purchas & Barton, 1976; Purchas et al., 1979). In 15- and 26-month-old red deer stags values ranged from 10.6 to 11.7 and 4.8 to 6.2 for loin and leg muscles respectively (Drew, 1984).

Comparisons between experiments however are seldom valid because of the different procedures used in terms of pre- and post-slaughter treatments, cooking times and temperatures, and even the site from which the core sample was taken.

## 5.11 PREDICTION OF CARCASS COMPOSITION

The close relationships between carcass weight and weight of carcass muscle ($R^2$ = 97.3), fat ($R^2$ = 81.3) and bone ($R^2$ = 79.5) are as expected from the slaughter of a single sex, single genotype group of animals. For male fallow deer between the ages of 13 and 25 months carcass weight alone may be an accurate enough indicator of carcass composition for the industry. With red deer the industry has used age and season of year as guidelines to achieve carcasses of desirable fat content.

Up to 25 months of age, and carcass weights of 36 kg, overfatness does not appear to be a problem in male fallow deer. At greater ages and/or carcass weights trimming of subcutaneous fat from carcasses may be required when animals are slaughtered between the months of January and May (Asher & Gregson, 1983).

Both kidney fat weight and fat depth 'C' explained further significant but small amounts (+ 11.2%, + 10.3%) of variation in carcass fat weight over and above carcass weight. These variables may warrent inclusion in a grading scheme. The use of fat depths would be the most readily adopted by the industry. Of the dissection variables tested none showed increases in $R^2$ values of great enough magnitude to warrent dissection procedures being used on these cuts. As well in the case of the shoulder it is not an easy joint to dissect. The weights of the shoulder bones would be easily obtainable if the packing house was boning out shoulders and these do increase the accuracy of prediction of carcass muscle and bone (see Table 4.35).

## 5.12 CONCLUSIONS

The results of this study have shown a number of differences between the carcass composition of fallow deer and that of other red-meat-producing species. The study has also highlighted a number of practical considerations for the production of fallow venison. Major conclusions from the study are enumerated below.

(1) Paramount amongst the differences between the carcass composition of fallow deer and that of other domestic ruminants was the low amount of dissectible and chemical fat in the fallow carcasses. Fallow deer have approximately half the amount of carcass

fat of rams at similar carcass weights. They have much higher muscle content and higher M:B ratios at similar percentage carcass fat. Despite having lower fat content the yield of carcass is higher than from other traditional meat producing ruminants including red deer. The low percentage of carcass fat means that fallow deer produce a carcass of acceptable composition at weights close to mature weight.

(2) Despite having much lower absolute levels of carcass fat the pattern of tissue growth with increasing liveweight is similar to that exhibited by other species. With increasing carcass weight the percentage of muscle and bone decreases and the proportion of fat increases. The pattern of subcutaneous to intermuscular fat deposition is also similar with the amount of subcutaneous relative to total fat increasing at higher carcass weights.

(3) The (relative) redistribution of muscle, fat and bone over the carcass with increasing carcass weight was too small to be of great commercial significance. The proportion of the carcass in the primal haunch cut decreased by about 2.2% over the carcass weight range of 23 to 39 kg, but this was due to a decrease in bone weight relative to total carcass bone. The proportion of total carcass muscle in the haunch remained the same.

(4) As carcass weight increased the proportion of total fat on the saddle cut increased. It appeared to be a site of subcutaneous fat deposition as the bucks approached mature weights. The fact that this fat is deposited subcutaneously would make trimming possible. The flank cut also increased in relative fat content, but in this case it was intermuscular fat, and would make this cut less acceptable to consumers at higher carcass weights.

(5) From a practical viewpoint these results suggest that appropriate slaughter ages for producers will largely depend on market requirements. The decision to slaughter at 1 or 2 years of age will depend on the venison price and whether there is a price differential for venison up to a carcass weight of 40 kg. In this study 2-year-old buck carcasses were 11 kg heavier than those from 1-year olds. The consumer acceptance of higher carcass weights is likely to depend mostly on their stipulations for carcass fat; which in this study increased from 7.3 to 11.7% between one and 2-year-old animals and between 6.0 and 9.9% in the primal cuts. The advantage of heavier carcass weights is the greater flexibility in terms of the further processing of the cuts and they still have a very low percentage fat compared to other species.

(6) The 17-month-old bucks, slaughtered in early winter, produced carcass which did not differ in proportions of muscle, fat or bone from M13 carcasses, other than could be explained by their greater carcass weight. The only practical advantage of retaining yearling bucks for slaughter in early winter would be to obtain higher carcass weights, or to give continuity of supply to the chilled product markets. However in many environments the cost of feeding over this period may not warrant the additional 3 kg carcass weight achieved.

(7) From a carcass grading viewpoint a major conclusion of this study is that carcass weight explained some 81% of the variation in carcass fat. The addition of a fat depth 'C' measurement enabled a further 10.3% of total fat variation to be explained while kidney fat added 11.3%. Either of these measurements in combination with carcass

weight would be useful in the formation of a grading system. The former probably being more acceptable in practise.

(8) Slaughter procedure appeared to influence meat quality to a much greater extent than age or carcass weight. The darker muscle colour and higher water-holding capacity of the 13-month and 25-month-old bucks slaughtered at a Deer Slaughter Premises may have been due to greater preslaughter stress in these animals compared to those shot in the paddock.

(9) The final conclusion, assuming between laboratory comparisons for meat tenderness can be accepted, is that meat tenderness results from this study suggest that fallow muscle may be more tender than that of other species, including red deer.

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