# INVESTIGATIONS INTO VARIATION IN GROWTH PERFORMANCE OF CATTLE AT PASTURE

A dissertation submitted in partial fulfillment of the requirements for the Masters in Applied Science (Animal Science) at Massey University

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## ERRATA

| | |
|---|---|
| Page ii Line 19. | Bulls gained 18% *more weight* than steers… |
| Page ii Line 24. | 1.45-1.70 *(not 1.45-170).* |
| Page ix. | Tables 2.2 -3.5 should be on Pages 35-54. |
| Page xiv. | M/D *ME concentration (MJ per kg DM).* |
| Page 8 Line 23. | *....exhibits……. It increases…* |
| Page 13 Line 7 *et seq.* | *...correlations…* |
| Page 13 Line 17. | ...hybrid *vigour…* |
| Page 16 Line 3. | *Baker et al. (1992)* |
| Page 17 Line 6. | ...than *Angus* cattle… |
| Page 17 Line 15. | Galbraith and Topps (1981), |
| Page 17 Line 26. | ...less *favourable…* |
| Page 19 Line 1. | ... of *their* own… |
| Page 19 Line 4. | They *used* several… |
| Page 20 Line 27 *et seq.* | Voisinet *et al.* (1997a)…P<0.05). These *authors* hypothesised… |
| Page 24 Line 12. | ...dictate *the* tests used. |
| Page 24 Line 28. | Ewbank *(1992)*… |
| Page 25 Line 26. | Tennessen *et al. (1984)* … |
| Page 26 Line 8. | Mohan Raj *et al.* (1992)… |
| Page 26 Line 22. | Brinks *et al.* (1962)… |
| Page 30 Line 7. | Holmes and Wilson *(1984)*… |
| Page 36 Line 16. | ...or *its* inverse… |
| Page 38 Line 15. | ...autumns *and* 0.12… |
| Page 41 Line 14. | ...14 days *post-weaning…* |
| Page 42 Line 2 . | ...in Table *3.1.* |
| Page 47 Line 22. | ...a covariate *where* appropriate… |
| Page 63 Line 27 *et seq.* | *...OMIs…* |
| Page 67 Line 21. | ...were not *repeatable…* |

## ABSTRACT

Burnham, D.L. 2000. Investigations into variation in growth performance of cattle at pasture. M.Appl.Sc.Thesis, Massey University, New Zealand. 89pp.

The aim of this experiment was to examine relationships between the growth rate (LWG) and estimates of voluntary feed intake, feed conversion efficiency (GFE), temperament, susceptibility to chronic (longer-term) stress, indices of mature weight and indices of metabolic rate within groups of similar cattle run together. Sixty Hereford x Angus cross 9 month old male cattle (30 bulls and 30 steers) were allocated to either the fastest growing two-thirds or slowest growing third (Restricted-Slow Group (RS)), based on their growth rate over a 100 day period commencing on d0. The fastest growing two-thirds were randomly allocated between the Fast (F) and Restricted-Fast (RF) groups. Restriction of growth of the RF and RS treatment groups commenced on d112. Treatment group F cattle (10 bulls, 10 steers) were grown rapidly to achieve slaughter weights of 550 and 525kg for bulls and steers at 16-18 months of age, respectively. Treatment group RS and RF were fed to achieve a similar weight at about 25 months of age. The trial was therefore a 3 x 2 factorial with 3 growth path groups and 2 castration groups.

Bulls gained 18% faster than steers in the F treatment group up to slaughter (1.10±0.03 and 0.93±0.03kg/d, respectively, $P<0.001$). No significant difference was found between liveweight gains of bulls and steers of the RF and RS groups (0.56±0.02 vs. 0.51±0.02kg/d, respectively, NS).

Organic matter intakes (OMI) measured using chromium intraruminal capsules ranged between 1.45-170,1.19-1.53, 0.89-1.02 and 0.94-1.20kg OMI/100kg LWT/d for the four separate intake periods. These values were all lower than predicted values, reflecting possible poor pasture quality and/or inaccurate measurement of OMI. During the d90-100 period under *ad libitum* feeding the bulls were significantly more efficient than the steers (0.24±0.01 vs. 0.18±0.01kg

LWG/kg OMI, P<0.001), and F and RF cattle had significantly higher feed conversion efficiency (GFE) than RS cattle (0.23±0.01 vs. 0.16±0.02 kg LWG/kg OMI, P<0.005). During the later intake periods the fast-growing F treatment group was significantly more efficient at food conversion than the restricted groups (RF and RS) on all occasions. No differences in temperament, as assessed by stepping rate and subjective scoring in a weigh crate, and flight distance measures, were found between bulls and steers. The RF treatment group had a consistently lower, but not always significantly different, temperament scores than the F or RS groups. Plasma cortisol levels were significantly (P<0.001) lower in bulls than in steers on all occasions. No sex differences existed in muscle glycogen content. Weight-adjusted withers heights was lower (P<0.05) in bulls than in steers on d208, 306 and 579, however there was no differences between the treatment groups. At slaughter the treatment F cattle had shorter carcass lengths, lighter livers, greater fat depths and kidney fat weights (P<0.001) than the RF and RS groups. Bulls had shorter femur bones, lower fat depth and kidney fat weight and liver weights, than steers (P<0.005) of the same carcass weight.

Relationships were evaluated across all 60 cattle together by expressing each trait as a residual for each animal relative to the mean for its sex by treatment group. Measures of average daily gain, OMI, GFE and muscle glycogen levels were not very repeatable over time as measured by correlation coefficients. Temperament indices (range 0.31-0.71, P<0.05) and cortisol levels (range 0.29-0.48, P<0.05) were repeatable over time. Weight-adjusted height measurements (range 0.36-0.48, P<0.01) were also repeatable when all 60 cattle were measured. Relationships were investigated between various measurements and LWG prior to the measurement, LWG to 16 months of age and LWG to slaughter. No significant consistent relationships were observed between various long-term growth rates and either GFE, temperament, indices of-mature weight or -chronic stress. Moderate but inconsistent relationships were found between OMI and longer-term gain. It appears from this study that no consistent relationships

between the various measurements and longer-term LWG exist in the cattle studied.

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# TABLE OF CONTENTS

## LIST OF TABLES

## TABLE OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ADG | average daily gain |
| B. | Bos |
| cm | centimetre (m $x10^{-2}$) |
| CP | crude protein |
| d | day |
| DM | dry matter |
| DMI | dry matter intake |
| °C | degrees Celsius |
| g | grams |
| GFE | gross feed efficiency |
| hd | head |
| ha | hectare |
| kg | kilogram (g $x10^{3}$) |
| kJ | kilojoule (j $x10^{3}$) |
| km | kilometre (m $x10^{3}$) |
| l | litre |
| LWT | liveweight |
| LWG | liveweight gain |
| µl | microlitre (l $x10^{-6}$) |
| µm | micrometre (m $x10^{-6}$) |
| µmol | micromol (mol $x10^{-6}$) |
| m | metre |
| M/D | ME content per kg DM |
| ME | metabolisable energy |
| MEI | metabolisable energy intake |
| mg | milligram (l $x10^{-3}$) |
| MJ | megajoule (J$x10^{6}$) |

| | |
|---|---|
| ml | millilitre ($1 \times 10^{-3}$) |
| mm | millimetre ($m \times 10^{-3}$) |
| mmol | millimols ($M \times 10^{-3}$) |
| ng | nanogram ($g \times 10^{-9}$) |
| n | number |
| NS | not significant |
| OM | organic matter |
| OMI | organic matter intake |
| % | percentage |
| P | probability |
| pm | after noon |
| ® | registered trademark |
| rpm | revolutions per minute |
| SE | standard error |
| vs. | versus |
| w/v | weight per volume |
| wt-adj. | weight-adjusted |

# CHAPTER 1. INTRODUCTION.

It has long been known that under identical conditions individual cattle will differ in growth performance. Many factors may be responsible for this variation including nutritional, genetic, physiological and behavioural traits. Some of these areas have been extensively researched under extensive pastoral systems.

Nutrition plays an important role in determining the growth performance of an animal. While much is known about the effects of various nutritional treatments on animal performance, less is known about what role nutrition has in determining the different performances of similar animals grazing together. Two possible sources of such variation include differing voluntary feed intake (VFI) and differing feed conversion efficiency (GFE). That is to say, cattle which grow faster may do so because they eat more, or alternately, they may grow faster due to the ability to convert feed to weight gain more efficiently.

Little is known about how ethological characteristics affect growth performance. This is a large area of animal science and one in which relatively few researchers specialise in, hence research data is sparse. Many of the processes that an animal uses to react to stimuli - such as mounting behaviour, movement, fighting and trembling - all require the expenditure of energy, thereby raising the energy requirement for maintenance. This energy may have otherwise been available for growth.

Social interaction will occur within any group of animals and may cause chronic or long term stress in some individuals. Likewise the inherent temperament of an animal may have an effect on the growth performance of that animal. Several researchers have demonstrated a relationship between temperament and growth

performance in feedlot situations, but information under less confined pastoral situations is not so prevalent.

Mature weight is an important factor in relation to growth. A larger frame size score at a given time is indicative of higher mature weight and vice versa. Animals growing towards a higher mature weight will normally grow faster at any particular age or weight up to the time of maturity.

The objectives of this study were therefore to determine the extent to which the faster growing cattle in groups of similar animals run together on pasture were those that exhibited:

Higher voluntary feed intake,

Greater feed conversion efficiency,

Higher measures of potential mature weight,

Calmer temperament,

Lower susceptibility to chronic (longer-term) stress.

# CHAPTER 2. REVIEW OF LITERATURE

In the following review the principles animal growth with regard to muscle, fat and bone growth, and the endocrinological control of growth are outlined as background material leading to the discussion on relationships between growth and various factors. Patterns of growth over time, and the relationship between maturity and growth are then discussed. Animal factors such as mature weight, sex, breed temperament and chronic stress are discussed in relation to animal growth, as are nutritional factors such as metabolisable energy, digestibility of feed, and intake of the animal. Relationships between visceral organ size and metabolic rate, and measures of temperament and stress are reviewed with respect to their possible effects on growth rate.

## 2.1. Principles and Patterns of Growth

### *2.1.1. Principles of Growth*

Growth is defined as an increase in tissue mass and includes not only cell multiplication (hyperplasia) but also cell enlargement (hypertrophy) and incorporation of certain environmental components (Owens *et al.* 1993). Components of animals relevant to meat production include muscle, fat and bone. Muscle contributes 50-66% of carcass weight (excluding head, feet and skin), fat 16-37% and bone 13-18% for animals in general (Kempster *et al.* 1982). In the following sections the basic patterns of development of muscle, fat and bone are reviewed.

#### *2.1.1.1. Muscle*

Muscles in the living animal are essential for posture and movement (Davies 1989a). There are 3 main types of muscle; skeletal (striated), smooth and cardiac (Currie 1988). Skeletal muscle is the predominant muscle involved in growth of the meat-producing animals. Muscle is separated into individual organs by loose

connective tissue sheets, which may contain intramuscular fat (Tornberg 1996). Muscle consists of principally of long thin muscle fibres, each of which is a single multinucleate cell or myocyte, formed by the fusion of myoblasts (Harper 1999).

The total number of muscle fibres is largely determined prior to or soon after birth in cattle (Harper 1999). Muscle growth is generally of two forms. Hypertrophic growth is the increase in diameter of the muscle fibre and can occur generally up to 12 months of age in cattle (Dreyer *et al.* 1977). This form of growth accounts for a large proportion of the change in size of skeletal muscle post-natally and is a combination of both fusion of satellite cells with existing myocytes and increased size of myocytes. Hyperplastic growth involves increased cell or nucleus number and occurs primarily prenatally (Allen *et al.* 1979) and only slightly postnatally (Bergen and Merkel 1991) although there is evidence that hyperplastic changes may continue until 19 months of age (Jurie *et al.* 1995).

*2.1.1.2. Fat*

The main functions of fat in the animal are to provide insulation and act as an energy store (Davies 1989a). Fat provides no mechanical function. Fat is distributed in the carcass in three locations. The subcutaneous depot lies on both sides of the superficial fascia and the cutaneous muscle layer. Intermuscular fat is found between muscle bundles while the cavity fat depot is found immediately beneath thin membranes within the body cavity and is especially thick around the kidneys and pelvic cavity.

Each fat depot is composed predominantly of adipocytes, which are spherical cells containing lipid (Lawrence and Fowler 1997). These are formed from adipoblasts, which are cells capable of producing lipid droplets. Adipose cells initially are 10-15μm in diameter but swell up to 200μm in some locations in cattle as lipid is stored (Roche and Quirke 1992).

Currie (1988) described the process of lipid metabolism, whereby lipids in the form of lipoprotein are transported to sites where they are broken down by lipoprotein lipase to release non-esterfied fatty acids available for uptake into the adipose cells, and glycerol which is transported on to the liver. The fatty acids are taken up by the adipocyte where they are incorporated into triglycerides within the cell. The newly formed triglyceride coalesces into the existing fat droplet. Under catabolic conditions, such as negative energy balance, lipases hydrolyse the stored fats so that fatty acids may be liberated from the stored form (Lawrence and Fowler 1997).

Adipose tissue is formed from the foetal stage, however maximal development occurs in the later stages of growth and development of cattle (Currie 1988).

*2.1.1.3. Bone.*

Each bone is an organ comprising of three distinct regions (Lawrence and Fowler 1997). The cortex is a collagen matrix in which minerals are embedded as crystals. The medulla is the central cavity filled with vascular tissue that is progressively replaced with adipose tissue as the animal matures. The peristeum is the surface of the bone with the exception of the epiphysial plate. The peristeum is the site of increase in bone circumference, while bone elongation occurs at the cartilaginous epiphysial plate.

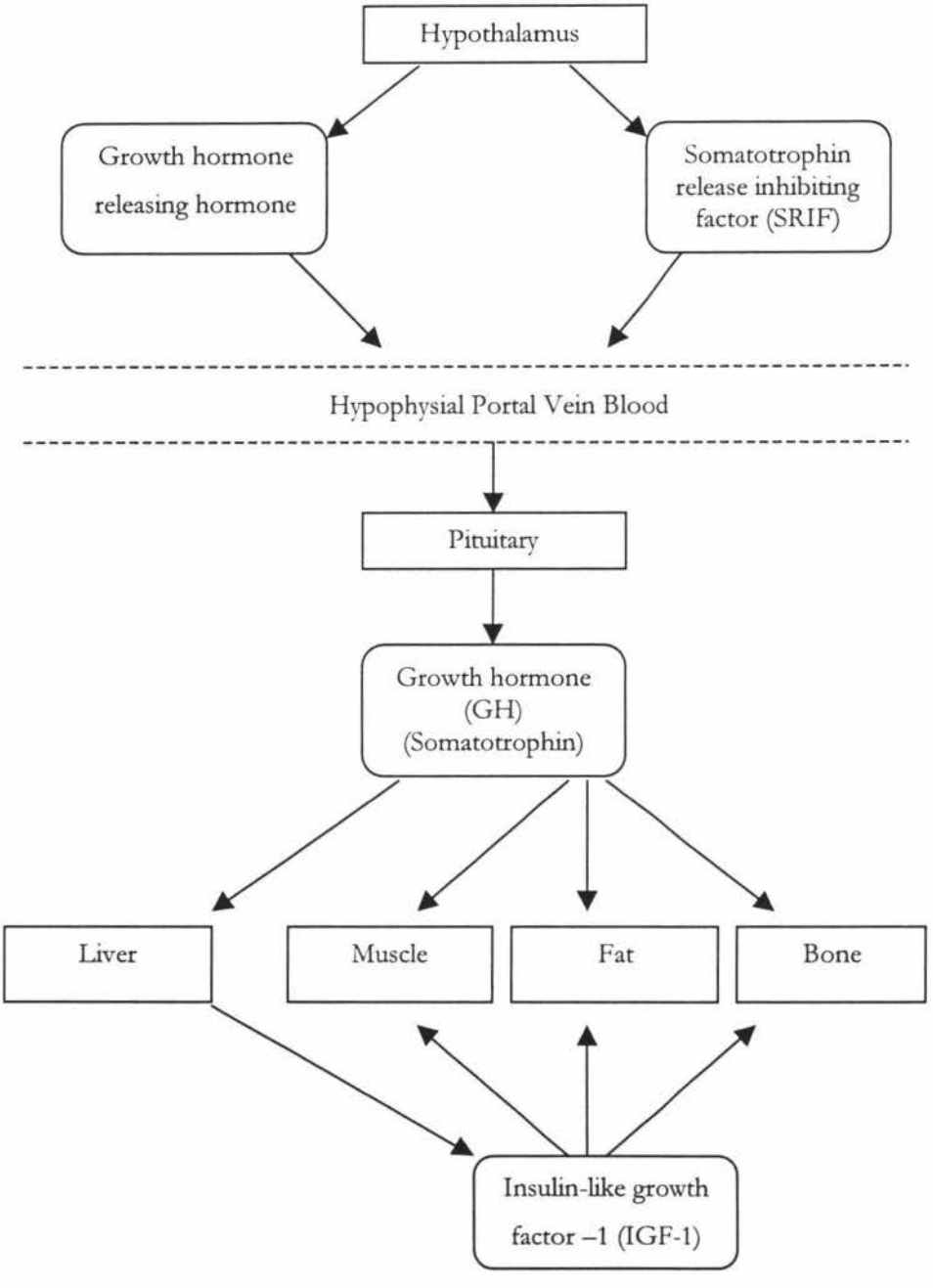
Currie (1988) describes bone as a tissue undertaking continuous turnover by apposition (anabolism) and resorption (catabolism). Osteoblasts secrete osteoid matrix in various locations (Lawrence and Fowler 1997). This matrix is mineralised by deposition of calcium phosphate salts. As the bone is mineralised, the osteoblasts become surrounded by minerals and are known as osteocytes. Resorption occurs by either of two processes, osteolysis and osteoclasia. Osteolysis is the most important and involves resorption of minerals to maintain calcium homeostasis.

### *2.1.2. Endocrinological Control of Growth*

Numerous endocrinological factors are believed to influence growth of tissues (Currie 1988). Growth hormone (GH, Somatotrophin) has roles in muscle anabolism and fat catabolism. It appears to act indirectly by stimulating the production of Insulin-like Growth Factors (IGF) (Lawrence and Fowler 1997). These are peptides capable of stimulating proliferation of myoblasts. Insulin is a major regulator of ongoing anabolism in muscle fibres and is important for general metabolic activity of cells. Gonadal steroids are also involved in muscle development by modulating the response of tissues to other hormones (e.g. GH) (Lawrence and Fowler 1997).

The release of GH from the pituitary gland is regulated by the release of Growth Hormone-Releasing Hormone (GHRH) and somatotrophin release inhibiting factor (SRIF, Somatostatin) from the hypothalamus into the portal blood system where they are transported to pituitary gland. (Bass and Clark 1989). GH enters the general blood circulatory system to be delivered to the liver and tissues. In the liver GH regulates the production of IGF-1. Both IGF-1 and GH have direct effects on tissue growth. Hence GH has a dual effect on growth, directly on the tissue and via the production of IGF-1, as proposed by (Greene *et al.* 1987). This regulatory pathway of GH is known as the somatotrophic axis (Figure 2.1.).

Figure 2.1. The Somatotrophic Axis (Bass and Clark 1989)



The response to GH release is determined by the concentration in the blood supply and also the pattern of exposure.

With the GHRH producing neurons being situated in the arcuate hypothalamus, which is intimately involved in regulation of feeding, level of feeding influences GH secretion with fasted animals exhibiting increased GH secretion and *ad-libitum* fed animals, lower GH secretion. GH also has a wide range of metabolic effects ensuring nutrient availability to growing tissues. The overall effect is to increase energy partitioning to these tissues.

Insulin secretion from the pancreas is primarily influenced by rises in blood glucose levels (Bass and Clark 1989). Insulin is primarily involved in increasing glucose uptake and suppression of glucose production, however, insulin also has a stimulating effect on the uptake of amino acid uptake by tissues. Insulin also inhibits protein degradation so that net protein deposition is enhanced. Insulin both promotes triglyceride formation and inhibits fat mobilisation. Lewis (1987: cited by Bass and Clark, 1989) showed that insulin increased lipogenesis in sheep subcutaneous fat.

Insulin-like growth factors (IGF-1, Somatomedins) play an important role in growth. They are generally considered a mitogen, in that they promote cell multiplication. GH promotes cell differentiation hence the two are required for growth.

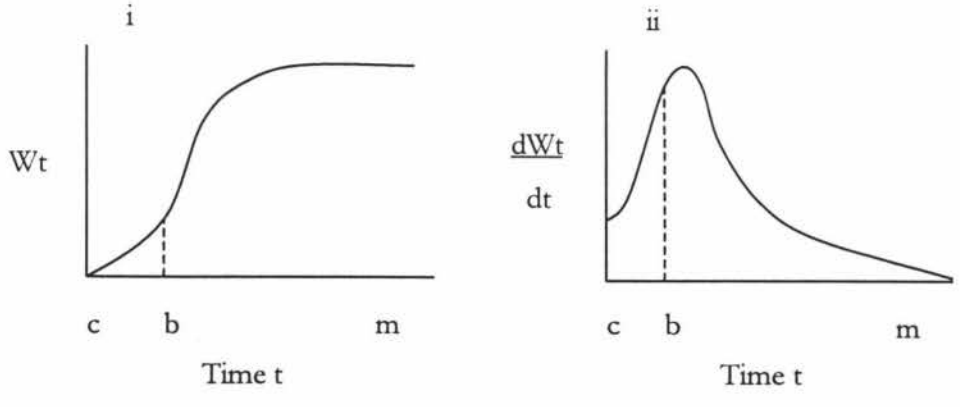
Cortisol is a corticosteroid produced in the cortex of the adrenal gland which exhibit counteractive effects to insulin (Bass and Clark 1989). They increase blood glucose by decreasing tissue glucose uptake and also increase protein and fat breakdown, which leads to increased insulin secretion.

*2.1.3. Patterns of Growth*

Growth is the result of a combination of cell multiplication (hyperplasia), cell enlargement (hypertrophy) or by the inclusion of extra-cellular material as described in section 2.1.1., and generally is a result of a combination of all of these. The end result of cellular growth is a change in dimension of the animal, which may be measured by weight, length, area or volume (Davies 1989b).

Davies (1989b) describes the different methods of analysing growth quite succinctly. Plotting a series of measures of the body over time, providing a sigmoid curve of accumulative growth (Figure 2.2.) can represent growth. The slope of the line is the accumulative growth rate, which increases to a peak at around 30-50% of the animal's mature size. He suggested that this method of growth analysis has the advantage of being quite readily understood but is possibly biologically misleading because an animal always grows as a multiple of its weight at a given time and hence a multiplicative growth model may be more appropriate.

Figure 2.2. Accumulative growth (i) and accumulative growth rate (ii) curves from conception (c) to birth (b) to maturity (m). Adapted from Davies (1989b)



Maturity is defined as the final stage of development at the end of the growth curve when muscle and bone for the first time reach a steady state, where the degree of maturity is the ratio of immature body weight to mature body weight (Davies 1989b). Taylor (1985) defined mature body weight as "the body weight of a normally grown, skeletally mature, normally active adult animal maintained in a state of body equilibrium on a standard diet, in a thermonuetral, disease-free environment with, or adjusted to, a chemical body fat of 20%".

Several generalisations regarding patterns of growth and how they are affected by mature weight can be stated as follows:

1. Growth potential of an animal increases with increasing mature size (Jones *et al.* 1981).
2. Reduction in energy intake has a larger effect on growth in "later maturing" animals with high growth potential than on "early maturing" animals (Geay and Robelin 1979)
3. Within breed and sex groups, heavier animals generally have heavier carcass weights relative to live weight therefore exhibit higher dressing out percentages (Kirton and Morris 1989)
4. Animals with a larger mature weight are generally leaner at a specified weight, heavier and fatter at a fixed age and heavier and younger when a specified fatness is attained (Cundiff *et al.* 1971).

Fowler (1968) suggested that growth has two aspects. The first is growth as measured in mass over time as discussed above, the second is changes in form and composition resulting from differential growth of the components parts of the body. Berg and Butterfield (1976) illustrated the relative growth rates of different carcass tissues as liveweight increases (Figure 2.3). Bone growth postnatally occurs relatively more slowly and earlier than muscle growth, therefore muscle to bone ratio increases as an animal matures (Davies 1989b). Fat grows at a steadily faster relative rate than the whole carcass, while muscle grows at a steadily decreasing rate as the animal grows toward maturity (Davies

1989b). Hence we observe a desirable increased muscle to bone ratio, and a less desirable increase in fat to muscle ratio as the animal matures (Kirton and Morris 1989).

Figure 2.3. Growth rate of carcass tissues relative to live weight. Adapted from Berg and Butterfield (1976)

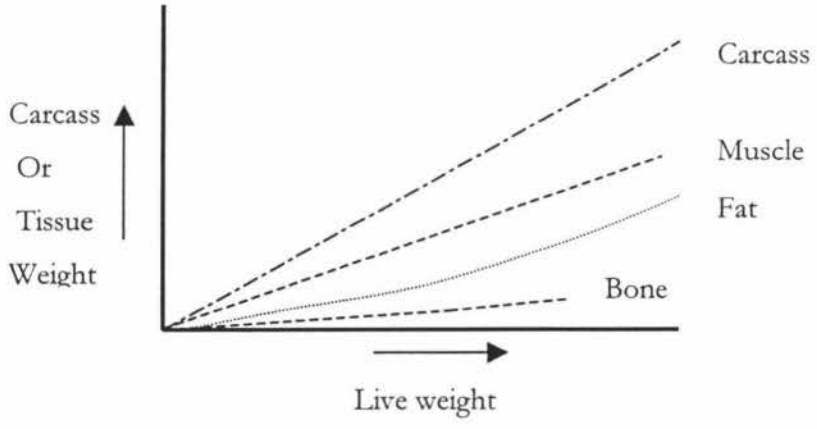
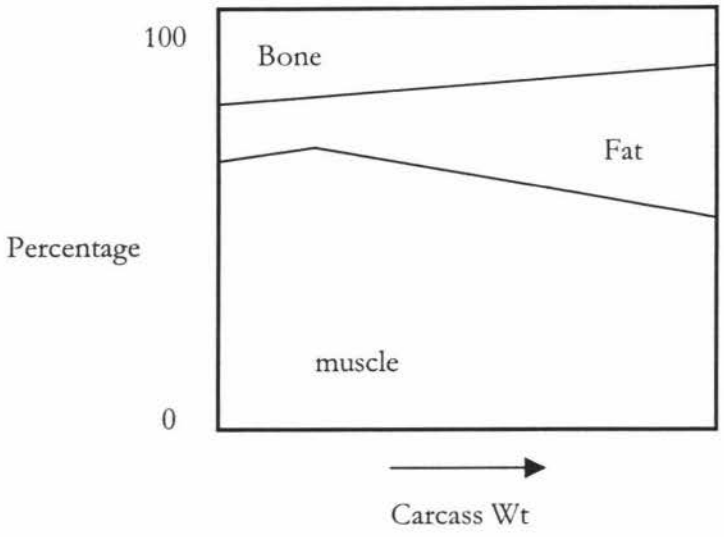



Figure 2.4 illustrates the change in proportion of muscle, fat and bone in the carcass as carcass weight increases (Berg and Butterfield 1976). As the animal matures, proportion of bone in the carcass weight decreases (Davies 1989b). This is primarily due to the early development of bone to provide structural support for the growing animal. Muscle proportion of the carcass weight is relatively high at birth, rising slightly soon after and then declining as fat deposition increases (Berg and Butterfield 1976). Fat proportion of the carcass weight increases with growth toward maturity, consequently "early maturing" animals have more fat at a given weight than "late maturing" animals (Davies 1989b).

Figure 2.4. Percentage of muscle, fat and bone in the typical carcass during growth. Adapted from Berg and Butterfield (1976)




## 2.2. Animal Factors Affecting Growth

Numerous factors have an influence on the growth of an animal. It is beyond the scope of this review to discuss all of these, but several relevant to this study will be considered. These include mature size, breed, sex, temperament and chronic stress. The heritability of growth trait factors will be discussed.

### *2.2.1. Mature Size*

Brody (1964)developed the classic empirical equation to predict body weight of many different species at different age. This equation was based on three parameters (mature body weight, growth deceleration rate (k) and age beyond conception (t)) where weight = mature weight $(1 - e^{kt})$. Owens *et al.* (1993) suggested that an increase in mature weight of 10% in Hereford-Shorthorn steers leads to a 15% increase in average daily gain between 200-500kg. Brinks *et al.*(1964) studied a number of weights for large numbers of Hereford heifers under range conditions in the United States of America, and found that weights

at all ages were positively correlated with mature size (0.28 and 0.57 for post-weaning gain and yearling liveweight respectively). Further analysis of this data by Taylor (1968) showed that any animal born at a proportion of mature weight above the average would continue to be above the average as a proportion of mature weight for all subsequent weights. Lickley *et al.* (1960) found a genetic correlation of 0.64 between mature size and average daily gain in Hereford yearling bulls. Significant positive correlation's of between 0.35-0.92, were found between liveweight gain of Hereford and Angus heifers with 36 month old weight over 18 years of data collected (Brown *et al.* 1972b). The lower correlation's corresponded to the earlier measures of average daily gain (4-8 month of age gain) and the higher correlation's with later measures (12-16 month of age gain). A correlation of 0.66 and 0.69 was found between 36 month weight and mature weight (Brown *et al.* 1972a). Andersen (1978) found a genetic correlation of 0.40 between mature weight and average daily gain of mature cows.

Many factors influence mature weight of beef cattle including age, season, management, site, genetic selection, breed and hybrid vigor (Kirton and Morris 1989; Owens *et al.* 1993). There is a lack of published data giving expected mature sizes of animals of different breeds and sexes, however Robelin and Tulloh (1992) cited values from various studies for bulls and cows of 1100-1200kg and 700-750kg for Charolais, 835kg and 540kg for Hereford, 800kg and 500-550kg for Aberdeen Angus, and 1000kg and 620kg for Holstein-Friesian. Meyer (1995) showed Hereford cows did not reach maturity until 5-6 years of age and mature (January) weight was approximately 600kg. Morris *et al.* (1989) in evaluating Angus cows selected for of adjusted weights at 13 months, 18 months or unselected found 6 year old weights approximately 535, 525 and 480kg respectively. Hammond (1961) stated that differences between breeds in size are due to differences in skeletal size and in the number but not the size of the muscle cells.

In summary, mature weight is positively correlated (range 0.57-0.69) with live weight at all ages although the correlation is stronger with later weights. Average daily gain is also positively correlated with mature weight (range 0.35-0.92) in the studies reviewed.

*2.2.1.1. Indicative Measures of Potential Mature Weight*

Davies (1989b) stated that defining or measuring mature body weight in practice is problematic as a value can only be determined by making certain assumptions. In practice an animal's weight fluctuates between- and within-years (Kirton and Morris 1989). In a typical beef finishing system animals are slaughtered before maturity is reached, hence indicators of mature size and rate of maturing are required to allow comparisons between different animals.

Owens *et al.* (1993) stated body composition at a specific fraction of mature weight is constant and therefore body composition measurement at any slaughter weight would permit prediction of mature body weight. Skeletal measures are often used as an indicator of mature weight (Meyer 1995). Hammond (1940; cited by Meyer 1995) argued that during development bones have a high priority and suffer less under low planes of nutrition, therefore they could be used to indicate an animal's inherent productive ability. Length of cannon bone in relation to body size has been found to be a good indicator of an individual's rate of approach to maturity with the genetic correlation between cannon bone length measured in early stages of life, and mature size being between 0.64-0.75. (Meyer 1995).

Some researchers have used a subjective frame score. Owens *et al.* (1993) state that frame size is directly related to mature weight. Ahlborn and Dempfle (1992) used a 9 point score where each unit increase score represented an increase of 5 cm height (1=<105, 2=105-109, etc.). They found a correlation between body weight and frame size of 0.76 for Friesian cows. Others have used wither height measurement as an easy-to-measure indicator of frame size as a replacement for

a subjective scoring system (McCurley and McLaren 1981; Burnham 1991). Owens *et al.* (1993) stated that frame size is usually measured as length of specific bones or wither height. Carcass traits such as length of carcass and femur bone length to weight ratio are other measures of skeletal size that may be used as indicators of future mature size. As previously discussed in section 2.1.1, fat to lean ratio and lean to bone ratio are all measures indicative of future mature weight.

In conclusion, in most trials cattle are slaughtered well before maturity, hence indicative measures of mature size are required. As bone growth is completed relatively early in life, body composition measures have been widely used as indicative measures of potential mature weight. Numerous body measurements have been successfully used including cannon and femur bone length, wither height, various frame scores, carcass length and various carcass ratios have all been used as indicators of potential mature body weight.

### *2.2.2. Breed*

Breed differences exist in growth performance of cattle, but much of this appears to be determined by differences in mature size (Renand *et al.* 1992). Robelin and Tulloh (1992) summarized data providing relative growth rates of bulls of different breeds (table 2.1). The ranking of the results was largely in line with the ranking in mature weight, with Charolais exhibiting the highest growth rate over 400 days and having the heaviest average mature weight, followed by Beef Shorthorn then Hereford then Aberdeen Angus.

Table 2.1. Growth rates and mature weights of bulls of different breeds. Adapted from Robelin and Tulloh (1992)

| Breed | Body weight (kg) | | Average daily gain (kg/d) | | Mature weight (kg) |
|---|---|---|---|---|---|
| | 100d | 500d | Actual | % of Charolais | |
| Charolais | 172 | 686 | 1.285 | 100 | 1100-1200 |
| South Devon | 157 | 590 | 1.082 | 84 | - |
| Hereford | 130 | 543 | 1.032 | 80 | 700-900 |
| Beef Shorthorn | 112 | 501 | 0.972 | 76 | 835 |
| Angus | 118 | 485 | 0.917 | 71 | 800 |
| Galloway | 91 | 469 | 0.945 | 74 | - |

Progeny of European cattle sires, such as Charolais and Simmental, have exhibited higher dressing-out proportions than those sired by British breeds (Kempster *et al.* 1982). Baker *et al.* (1990) examined eleven cattle breeds for crossbred beef production under New Zealand pasture management. The breeds were crossed with either Angus or Hereford cows. They found that offspring sired by European breeds had weights at 5 months and 13 months of age which were 6% and 5% heavier than Hereford x Angus and 11% and 11% heavier than straightbred Angus-sired progeny, respectively. This indicates that relative growth rate was different between European and British crossbred and straightbred Angus. Average daily gains were low at approximately 0.43, 0.41 and 0.38kg/d for European, Hereford x Angus and Angus offspring. Renand *et*

*al.* (1992) suggested that Angus growth rates are 24% lower than Charolais. *Bos indicus* cattle perform better than *B. taurus* in tropical environments (Seifert 1971; Frisch 1973)

To summarise, breed differences appear to exist in relation to growth rate with European breeds exhibiting faster growth than British breed of cattle. Charolais grow faster than Hereford which grow faster than angus cattle. Much of the difference in growth rate of different breeds appears related to mature weight differences. *B. indicus* cattle perform better than *B. taurus* in tropical climates.

### *2.2.2. Sex and Castration.*

It is accepted that sex of the animal plays an important role in determining the growth ability of an animal. With cattle, bulls have been shown to exhibit 10-20% greater growth than steers under good growing conditions (Galbraith and Topps 1981; Purchas 1991). Baker *et al.* (1992) stated that bulls have faster leaner growth by 10-15% both indoors and out at pasture. Kirton and Morris (1989) suggested that heifers grow slower than steers, however Galbraith and Topps (1981) suggested that heifer and castrates show similar growth. Galbraith and Topps, in a review of the effects of hormones on growth, also suggested that bulls are also more efficient converters of food than steers by 10% (range 0-15%). Purchas and Grant (1995) found that Friesian cross bulls exhibited 13.7% and 22.3% superior growth over steers, over two seasons respectively, when run together at pasture. Knight *et al.* (1999) found bulls grew faster than steers (0.89±0.02 vs. 0.78±0.02kg/d respectively) over approximately 265 days. Some, however, have found that the advantage of bulls over steers was less clear when conditions are less favorable (Price and Yeates 1971; Mickan *et al.* 1976). Bulls usually have a slightly higher dressing-out proportions than steers by 1-2% (Galbraith and Topps 1981; Kirton and Morris 1989).

In summary, bulls grow faster than steers by 10-20%, and steers may grow faster than heifers although this difference is less clear. Differences between sex types

appear to be dependent on feed conditions with less pronounced differences under less favourable conditions.

### *2.2.3. Temperament*

Temperament is defined as the response of cattle to man (Fordyce *et al.* 1985). They comment that terms such as nervous, flighty and poor temperament, are used for cattle which take flight when approached by man, which are aggressive toward man or which sulk during handling. Phillips (1993) suggested that temperament may be defined as a major parameter in the personality or mood of cattle in relation to their reaction to man and that temperament should be measured in relation to its fearfulness and not aggressiveness toward man. Fordyce *et al.* (1988) stated that temperament can be generally related to fearfulness. Perhaps the best definition of temperament is that of Voisinet *et al.* (1997b) who state that temperament generally means the excitability or tendency of an animal to become agitated when handled.

Very few published reports have related temperament to growth of cattle. Tulloh (1961) reported a weak but positive relationship between his measure of docility and liveweight of beef cattle indicating that docile steers and heifers grew better than restless, nervous, wild or aggressive animals. The author used pasture grazed Angus, Hereford and Shorthorn steers and heifers. He used a descriptive score of 1 docile to 6 aggressive for cattle in a head bail and for analysis, he divided animals into 2 temperament groups ("desirable" = score 1 and 2 and "undesirable" score 3-6) and at the same time divided them into 2 weight groups (above the mean and below the mean). When analysed with a $X^2$ test using Yates correction the relationship between liveweight and temperament was significant ($P<0.05$). Tulloh (1961) found that Herefords and Angus had significantly lower temperament scores than Shorthorn cattle. Tulloh suggested that selection for liveweight gain could result in an associated improvement in temperament.

Fordyce and Goddard (1984) cited unpublished data of there own in which they found a low negative correlation between temperament scores and weight gain in young cattle. Fordyce *et al.* (1985) examined 220 ½ to ¾ cross *Bos indicus* steers grazed at pasture. They several measures of behaviour (degree of audible respiration, movement vigour, bellowing, kicking and going down) assessed when the animals were held in a race for 1 minute. They found a significant ($P<0.01$) a negative correlation of –0.34 between temperament score and live weight, such that heavier animals had lower temperament scores. Fordyce *et al.* (1988) scored various movement and other behaviours to calculate a temperament score of 170 bulls and 240 cows. They found that heavier animals tended to have lower temperament scores but the differences were not significant.

Voisinet *et al.* (1997a) published work in which they examined 436 cattle (steers and heifers) of 6 breeds of which 3 were *Bos taurus* and 3 were *Bos indicus* cross breeds in a feedlot operation. They assessed temperament using a 1-5 scale (1 calm – 5 violent struggling) in a weighing crate where the cattle were unrestrained and a 1-4 scale (1 calm – 4 violent struggling) in a squeeze chute (crush). They found that *B. indicus* cattle had had higher mean temperament ratings than *B. taurus* cattle ($3.45\pm0.09$ vs. $1.80\pm0.10$ respectively, $P<0.001$). The *B. taurus* steers with the calmest temperaments (score 1) had 0.19kg/d higher average daily gains than those with the highest temperament scores (score 5) in the weigh crate test. The *B. indicus* steers and heifers (with the exception of the 4 animals with a temperament score of 1) which had the calmest temperaments (score 2) had 0.10kg/d higher average daily gains than those with the highest temperament scores (score 5). The *B. indicus* cattle with temperament score 1 had very low liveweight gains compared with all the other cattle and the authors excluded these as there were only 4 animals and exhibited a large standard error. In the crush test the *B. indicus* cattle with lower temperament scores (1) also grew 0.10kg/d faster than those with high scores (4).

Several other studies have shown a relationship between temperament rating and growth rate. Immonen *et al.* (2000) found a significant negative correlation between liveweight gain and temperament of –0.157. Wulf *et al.* (1997) found the ADG was negatively correlated with temperament with a value of –0.58. Burrow and Dillon (1997) studied two cohorts of *B. indicus* cattle in a feedlot. They found that the first cohort had a poorer temperament as measured by flight speed (the time taken for the animal to travel 1.7m after leaving a weighing crate) than the second cohort (51% vs. 12% with fast flight speeds). They also found that animals with a slow flight speed in the first cohort gained weight more rapidly. The relationship between growth and flight speed observed in the second cohort was not significant, although the animals with the fastest speeds had the lowest liveweight gains.

Blockey and Lade (1974) examined dominance of 52 Hereford beef bulls at pasture and the relationship with growth and found that growth rate was positively correlated with dominance (0.40, $P<0.025$) when feed was scarce and the animals were not being fed supplements. This correlation was not evident when pasture was abundant (0.03, NS). Blockey (1979) found that dominance and aggression in Hereford and Angus bulls was not related to production factors in a post-weaning fattening test. This is also supported by Fordyce *et al.* (1985) and Phillips (1993). Nicol and Meikle (1997) examined the adjustment of bull to steer ratio on agonistic behaviour in cattle and found that as the ratio declined from 100:0 toward 30:70 bulls to steers, the agonistic behaviour of the bulls declined markedly from $0.83\pm0.12$ to $0.49\pm0.12$ incidents/animal/hour.

Several of the above studies examined differences between sex with regard to temperament. Tulloh (1961) found no significant difference between steers and heifers although the author stated that the steers appeared to have better temperament than heifers. Voisinet (1997a) found that heifers had higher scores than steers in the weigh crate ($3.72\pm0.11$ vs. $3.39\pm0.11$ respectively, $P<0.01$) and in the crush ($2.23\pm0.10$ vs. $1.97\pm0.10$ respectively, $P<0.05$). Voisinet

hypothesised that sex differences may be evident only in certain breeds as the low temperament scores found in *B. taurus* cattle may lead to less pronounced differences. Wulf *et al.* (1997) found steers had lower temperament than heifers, however others have found no difference between heifers and steers (Stricklin *et al.* 1980), steers or bulls (Tennessen *et al.* 1984) or heifers and bulls (Shrode and Hammack 1971).

Burrow (1997) in a review of measures of temperament in different livestock species stated that average heritability of 10 unrestrained and 34 restrained temperament tests was 0.36 (range 0.16-0.70) and 0.23 (range 0.00-0.67) respectively. She stated that even though great differences exist between different species, tests, previous experience of animals and experimental settings, the estimates of heritability of both restrained and non-restrained tests were generally moderate to high.

Heritability estimates for temperament varies. Hearnshaw and Morris (1984) found heritability of 0.03±0.28 *B. taurus* and 0.46±0.37 for *B. indicus* cattle. Phillips (1993) summarised 13 studies and found a range of heritabilities of between 0.03-0.53. He suggested that temperament in the crush has variable heritability (0.0-0.4), greater measures of heritability are found when the animal is challenged by head restraint. Phillips also suggested that temperament in *B. indicus* cattle is greater that *B. taurus*. This may be due to selection (intentional or non-intentional) in *B. taurus* for better temperament. Tulloh (1961) suggested that selection for liveweight gain may lead to improved temperament. It may also be due to early-life handling of *B. taurus* cattle as management systems animals are exposed to in early life have a significant effect on later temperament (Boivin *et al.* 1992; Le Neindre *et al.* 1995). Temperament therefore is a result of both genetics and previous experience (Grandin 1993; Phillips 1993)

In summary, temperament is defined as the response of cattle to man in terms of fearfulness, and is unrelated to dominance in the social structure of the herd.

Relationships of fearfulness with growth rate have been negative, but few studies have investigated this. *B. taurus* cattle are calmer and less fearful than *B. indicus*.. Differences between the sex or castration types are less clear with some studies finding steers calmer than heifers and others finding no differences. Heritability of temperament is dependent on the test used and species involved, but it appears temperament is moderately- to highly-heritable.

*2.2.3.1. Measures of Temperament*

. In a review of relationships between measures of temperament with performance traits of beef cattle, Burrow (1997) summarised the various tests for the temperament of individual animals of different species of livestock. She categorised temperament tests into non-restrained, restrained, ease of movement, dairy temperament, dominance and maternal temperament tests. Dominance, dairy temperament and maternal temperament are not relevant to this study so they will not be discussed.

During non-restraint tests the animals being assessed are free to move within a relatively large area in the presence or absence of an observer (Burrow 1997). This category includes flight distance (Murphey *et al.* 1980), flight speed and response to novel stimuli tests. Flight distance is the radius of surrounding area within which an intrusion of man invokes a flight reaction (Grandin 1980). Morris *et al.* (1994) found that good temperament generally means the animal has a small flight distance. Baker and Gonyou (1986) found that flight distance decreased when measured over time. Flight distance may range between 1.5-7.6m in feedlot cattle and 30m in cattle from mountain ranges (Grandin 1980). Flight speed is the time taken for an animal to move a set distance after exiting a weighing scale into an open yard (Burrow and Dillon 1997). It has also been measured using a 1-6 scoring system (Morris *et al.* 1994). Burrow (1997) suggested that this test measures the fear response of an animal to being handled by a human rather than fear of the human specifically, as is the case for approachability and flight distance tests. Response to novel stimuli involves

observations of the reaction of an animal to a novel object or animal in either a large yard or open field (Burrow 1997). The speed at which the animal approaches the stimuli and/or distance approached is usually measured. This is likely to measure the fear/exploratory response to the novelty. Tilbrook *et al.* (1989) measured the behavioural response of bulls in a 6 x6m arena to the introduction of an observer seated along one wall of the arena. They stated that the basis for equating the amount of approach behaviour to the observer with fear of humans is the assumption that differences between animals in their inquisitiveness are minimal.

Restrained tests involve the animal movement being physically restrained by area (i.e. small pen, race or weigh crate) or by mechanical apparatus (i.e. crush or head bail). Movement and struggling are generally assess using scoring systems (Tulloh 1961; Hearnshaw and Morris 1984; Fordyce and Goddard 1984; Grandin 1993). Phillips (1993) suggested that measurements in a crush or weigh crate represent reaction to confinement as well as human presence.

Ease of movement tests generally measure the time taken to move cattle through a series of yards, races or other facilities. Baker and Gonyou (1986) measured time taken for bulls to enter, stand still and leave a weighing crate. Tilbrook *et al.* (1989) measured the time for an animal to move through a novel race and yard system. They stated that ease of movement tests confound the reaction to humans with other stimuli such as reaction to novel environments and effect of group mates in the response. Burrow (1997) stated that it is difficult to determine exactly what these tests measure as fast times could mean that the animals are more docile, and hence less afraid to move through the facilities, or that they have a higher level of fear of the humans pushing them through.

Tulloh (1961) stated that the effectiveness of a score for temperament is largely dependant on the degree of variation shown when observed and that temperament of an individual cannot be assessed based on observations on one

occasion due to day-to-day variation, however temperament of a group could. Fordyce and Goddard (1984) found repeatability between assessment of temperament of between 0.28 and 0.52 for five of six measurement occasions. Hearnshaw and Morris (1984) found repeatability of 0.43±0.09 for measures of cows and calves on two occasions. They also found high repeatability between operators assessing the same animals on the same day. These ranged from 0.67±0.08 and 0.82±0.08, suggesting that their 0-5 crush score was an effective measure of temperament in cattle. Grandin (1993) found that agitation of an animal in a crush was generally persistent over time.

There are numerous tests for temperament. Factors such as facilities available, management practices and other manipulations to be performed (such as weighing etc) appear to dictate that tests used. This makes comparison between different research results difficult. There appear to be advantages and disadvantages in all tests used. Restrained tests such as crush and headbail tests, have been widely used although some question remains as to the confounding effect of the restraint on the reaction measured. Non-restrained tests such as flight distance appear to provide good indicators of temperament, however flight distance has been shown to decrease over time. Movement scores can be difficult to interpret as fast movement may indicate confidence or fear. Generally good repeatability of all tests between operators and between measures on different occasions have been found.

### *2.2.4. Chronic Stress.*

Ewbank (1992) discussed stress in farm animals and the response to it. He defined stress as having to carry a biological cost for adapting or attempting to adapt to damage or the threat of damage from the environment. Archer (1979) defined stress as the prolonged inability to remove a source of potential danger, leading to an activation of systems for coping with danger beyond their range of maximum efficiency. Ewbank suggested that the current tendency is to think of response to stress as a quick adrenaline response ("fight or flight") followed by a

slower developing but more prolonged corticosteroid response. A chronic stressor may induce the corticosteroid response without obvious "fight or flight" reaction.

Mitchell *et al.* (1988) stated that the increased concentration of cortisol indicates increased activity of the hypothalamic – adrenal cortex axis. One of the main functions of increased corticosteroid release into the blood is to help liberate glucose for use by muscle and the brain in periods of stress (Carragher and Matthews 1996). Chronically elevated corticosteroid levels are known to have a catabolic effect on body reserves (Dickson 1977).

Cortisol has been widely used as a measure of chronic stress in live animals (Tennessen *et al.* 1984; Warriss *et al.* 1984; Mitchell *et al.* 1988; Mohan Raj *et al.* 1992; Grandin 1997; Carragher *et al.* 1997; Schwartzkopf-Genswein *et al.* 1997) at slaughter (Cockram and Corley 1991) and following a challenge with adrenocorticotrophic hormone (ACTH) (Fisher *et al.* 1997). Cortisol baseline levels in unstressed cattle collected remotely at pasture were 4.3±0.8ng/ml (Carragher *et al.* 1997) and 4-18ng/ml in yearling feedlot cattle (Schwartzkopf-Genswein *et al.* 1997).

Grandin (1997) found baseline values of 0.5-9ng/ml in her review. Restraint in a headbail produced cortisol levels of 13-63ng/ml in the studies reviewed. Tennessen *et al.* (1984) found trucking for 10 minutes and 2 hours elevated cortisol levels. Carragher *et al.* (1997) found that cortisol was elevated ($P<0.05$) on d7 and d14 post surgical castration of bulls. Mohan Raj (1992) found that mixing steers and bulls resulted in increased cortisol levels. Mitchell (1988) examined handling and transport of Brahman cross cattle and found that handling cattle elevated cortisol from 25.0±13.7mmol/l to 176.7±65.5mmol/l.

Tennessen found that steers had higher cortisol levels than bulls and suggested this could be caused by altered steroid balance in castrated animals. Mohan Raj *et*

*al.* (1992) however found no differences between bulls and steers in plasma cortisol or muscle glycogen levels, however lactate and glucose were higher in steers.

Muscle glycogen has been used to indicate muscle activity and stress (Lacourt and Tarrant 1981). Carragher and Matthews (1996) stated that animals that respond actively to a stressor will tend to deplete glycogen levels in their muscles during resistance or escape. Level of muscle glycogen of bulls at pasture is between 80 to 100 mmol/kg (McVeigh and Tarrant 1982). Mohan Raj (1992) found that mixing steers and bulls resulted in no effect on muscle glycogen levels (2.62 vs. 3.73μmol/g respectively, NS).

To conclude, plasma cortisol has been widely used as an indicator for chronic stress and is known to be elevated following stress. Muscle glycogen is depleted in muscle during periods of high activity and therefore has been used to indicate "flight or fight" levels between animals. Both measures require some time to respond (10-20 minutes for cortisol levels) after the stressor and can remain changed for sometime, hence these are seen as better indicators of chronic stress rather than acute adrenaline or heart rate responses. Most of the studies reviewed examined metabolite response to some acute manipulation or stressor, for example trucking and castration. Few studies used these measures to examine chronic long-term stress.

### *2.2.5. Heritability of Growth Traits*

Numerous studies have examined the heritability of growth traits. Brinks (1962) found heritabilities of 0.57 and 0.62 for spring and autumn weights respectively. Meyer (1995) found heritabilities of 0.47 for average mature weight in Hereford cows, compared with 0.29 for mature weights treated as repeated records. He also found rate of maturing to be moderately heritable with a value of 0.32. Smith (1974) reported a heritability of 0.42 for mature weight and from 0.62-1.02 for immature weights. Body weight and stature showed heritabilities of 0.24 and

0.29, respectively, in Holstein-Friesian dairy cows (Ahlborn and Dempfle 1992). Kirton and Morris (1989) discussed heritabilities of carcass traits from New Zealand and American sources. The American sources showed heritabilities averaging 0.55, 0.48 and 0.40 for hot carcass weight, fat thickness and eye muscle area while the New Zealand sources showed heritabilities averaging 0.42, 0.20 and 0.23, respectively. The American sources also found heritabilities averaging 0.57 for fat trim weight and 0.72 for kidney fat weight. Taylor and Field (1999) cited heritability for post-weaning average daily gain as 0.45 and 0.30 for feedlot and pasture fed animals respectively. Heritabilities below 0.20 are considered low, those between 0.20-0.39 considered moderate and above 0.40 are considered strong (Taylor and Field 1999). Genetic correlations between average daily gain and different traits were calculated from over 2000 young bulls at 450kg were summarised by Andersen (1978). Genetic correlations with average daily gain were 0.40±0.15, -0.95±0.30, -0.61±0.19, -0.34±0.17 and 0.52±0.15 for birth weight, feed conversion ratio, dressing percentage, lean to bone ratio and lean to fat ratio.

In summary, mature weight appears to be moderately to strongly heritable (range 0.29-0.62), and average daily gain moderately heritable (range 0.30-0.45) in the literature reviewed. Various carcass measures of fatness showed strong levels of heritability of approximately 0.48-0.72.

## 2.3. Nutritional Factors affecting Growth

### *2.3.1. Metabolisable Energy and Digestibility*

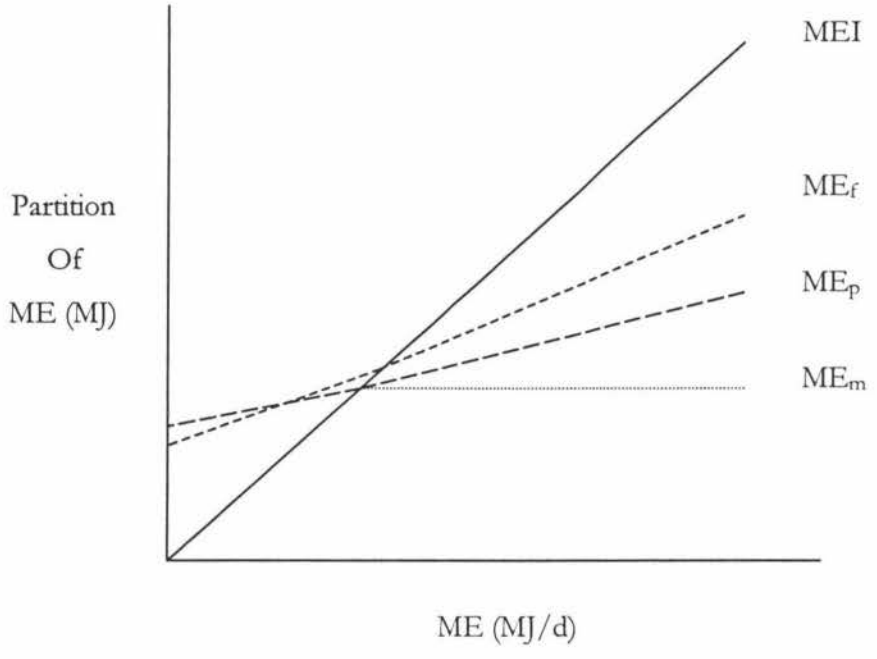
All animals require feed to provide energy and nutrients for maintenance of body functions and production. Webster (1993) stated that almost all metabolisable energy (ME) and protein contained in the food consumed by a growing animal are directed to heat production (maintenance) and the deposition of fat and protein. Metabolisable energy for maintenance ($ME_m$) is defined as the rate of heat production of an animal kept in a thermonuetral environment, when rate of

ME intake in the feed exactly balances heat loss rate (Lawrence and Fowler 1997). Estimates for $ME_m$ for non-lactating grazing beef and dairy cows show large variation, the average being close to $0.55MJ/kg^{0.75}/d$ (Geenty and Rattray 1987).

Geenty and Rattray (1987) discussed factors that influence the maintenance requirement of the ruminant. Metabolisable energy for maintenance ($ME_m$) is not constant and varies with size, age, quality of diet, availability of pasture, terrain and climate. $ME_m$ increases with increased body size due to increased surface area available for heat loss. Increased protein content of feed leads to an increase in $ME_m$, while higher digestibility of feed leads to a decrease in $ME_m$ and an increase in efficiency of gain ($k_g$). Low temperatures, wind and precipitation all potentially increase heat loss, which leads to increased $ME_m$. Topography, paddock size, feed and water availability can all affect the amount of energy expended by the animal to harvest the feed and therefore $ME_m$. Sex also has an influence on $ME_m$ with bulls having about a 10-15% greater fasting heat production (FHP) than steers or cows (ARC 1980; Geenty and Rattray 1987).

Webster (1985) determined that the relationship between retained energy above $ME_m$ and liveweight gain is determined by the composition of the liveweight gain. Protein has a lower energy content (23.4kJ/g) than fat (39kJ/g). As level of feeding increases and rate of gain increases, the proportion of fat and net energy content of the liveweight gain also increases (Figure2.5) (Geenty and Rattray 1987; Lawrence and Fowler 1997). Fat deposition is more efficient than protein deposition (0.70 vs. 0.1-0.3), however, on a feed conversion efficiency basis (kJ/g gain) lean gain is more efficient than fat because lean gain contains a high proportion of water. Generally speaking during continuous growth the proportion of fat in the body gain increases as the animal approaches maturity and therefore so does the energy value of the gains (Webster 1985).

Figure 2.5. Relationships between metabolisable energy intake (MEI) and the partitioning of energy into maintenance ($ME_m$), protein deposition ($ME_p$) and fat ($ME_f$) deposition (Lawrence and Fowler 1997)




Organic matter (OM) is the energy yielding portion of the feed and the digestibility of this (OMD) is calculated using the formula (Geenty and Rattray 1987) *OMD = (feed OM - faecal OM) / feed OM.* The digestible organic matter digestibility as a proportion of the dry matter (DOMD) is calculated using the formula *DOMD = (feed OM - faecal OM) / feed DM.* ME content of pasture is usually expressed as M/D (MJ ME/kg DM) at a maintenance level of feeding where *M/D = 0.16DOMD* (Geenty and Rattray 1987).

Temperate pastures usually have OMD's ranging from 55-80% throughout the year when grazed by cattle or sheep (Ulyatt 1981). Estimated M/D values range from 8.0 to 12.8MJ ME/ kg DM in pastures of 56% to 86% OMD (ARC 1980). Level of feeding, animal species and physiological effects alter the digestibility

and M/D values of feed however the size of these effects do not warrant their consideration in altering the values (Geenty and Rattray 1987). Geenty and Rattray (1987) cited M/D values of 10.8, 11.2, 12.0, 10.3 and 8.0 for autumn, winter, spring, summer-leafy and summer-stalky perennial ryegrass (*Lolium perenne* – white clover *(Trifolium repens)* pastures respectively.

Crude protein (CP) requirements for cattle are generally in the range of 100-120g CP/kg DM (Geenty and Rattray 1987). Holmes and Wilson (1998) stated the CP in pasture ranges from approximately 100-200g CP/kg DM in mature stalky pastures to 200-300g CP/kg DM in immature rapidly growing leafy pasture. CP of pasture is generally in excess of the stated requirements, but despite this CP may sometimes limit grazing ruminants (Geenty and Rattray 1987).

In conclusion, maintenance requirement of energy at a set weight is variable in cattle and is dictated by factors such as age, body composition, protein content and digestibility of the feed, feed supply, physiological status of the animal and environmental factors. As the energy available for liveweight gain is that which is left after maintenance, this variability suggests that variation in efficiency of energy utilisation for maintenance could be an important determinant of variation in growth rate. Composition of gain is also important in determining growth rate, as the gain of muscle tissue is more efficient on a weight gain basis than the gain of adipose tissue.

*2.3.1.1. Relationships between Visceral Organs and Metabolic Rate.*

Smith and Baldwin (1974) found that liver, heart, mammary tissue and tissue of the gastrointestinal tract were among the more metabolically active tissues in the body. They hypothesised that increases in the maintenance requirement of dairy cows during lactation is partly due to changes in the relative size of these tissues and organs. Early *et al.* (1990) found that protein turnover was higher in visceral tissues than in skeletal tissue. Ferrell and Jenkins (1985) illustrated that energy expenditure by visceral organs constituted a major proportion of the energy

required for basal metabolism. Ferrell *et al.* (1976) estimated from oxygen consumption of tissue slices that energy expenditures of the liver and heart represented 22% and 11% of the fasting energy expenditure of cattle respectively. Ferrell and Jenkins (1985) suggested that the high rate of energy expenditure was due to high rates of protein synthesis and that the relative proportions of these visceral organs in the body is likely to influence the maintenance requirements of cattle. Johnson *et al.* (1990) concluded that on a differential basis, increases in energy use by the liver and gastrointestinal tract appear to account for up to 70% of the heat increment of ME above maintenance. They summarised the literature by stating that the size of an organ will depend on the functional workload placed on that particular organ.

The influence of visceral organs on total energy expenditure can also be seen in the response of these organs to nutritional manipulation. Several studies have shown that cattle and sheep previously on a high plane of nutrition have increased weights or proportions of small intestine, liver and pancreas (Koong *et al.* 1982; Ferrell and Jenkins 1985). Others have shown that restricting diet to maintain liveweight has resulted in decreasing the proportion of metabolically active tissue and maintenance requirement (Seebeck 1973; Ledger and Sayers 1977). Webster (1993) suggested that since the mass of most metabolically active tissue, expressed as a proportion of lean body weight correlates closely with food intake, it could be expected that the proportional weight of the liver during unrestricted growth would be related to impetus for growth. Sainz and Bentley (1997) examined the cellularity of visceral organs in steers under different nutritional regimes. They found marked nutritional effects on liver growth between steers fed high- and low-concentrate diets, which were primarily due to changes in cell size with smaller changes in cell numbers. They concluded in their study that workload determines organ size, but dietary factors influencing workload clearly vary between different organs.

Terry *et al.* (1990)conducted a trial examining differences between cattle type in yields of carcass by-products. They found the liver weight as a percentage of carcass weight was 1.45±0.02, 1.46±0.30, 1.96±0.11% for British breeds, European breeds and Holstein-Friesian respectively, with the Holsteins having significantly heavier livers than either the European or British breeds ($P<0.05$). Other studies have also observed this difference (Ramsey *et al.* 1965).

Sainz and Bentley (1997) killed steers previously fed on different feeding regimes at 3 different weights and found heart weights of approximately 1.17kg, 1.43-1.56kg and 1.73-2.11kg for steers killed at 237, 327 and 481kg, respectively. Taylor and Murray (1991) examined body composition of fully mature cows (age > 5 years old at slaughter) of 5 different breeds including Hereford, Angus and British Friesian (5 of each breed) and found heart weights of 4.4, 4.4 and 4.2kg and liver weights of 8.4, 9.7 and 10.6kg, respectively.

To conclude, changes in size of metabolically active visceral organs such as liver, heart, mammary and gut epithelial tissue appear to be due to functional workload, may be partially responsible for changes in maintenance requirements of cattle due to higher protein turnover and high energy requirements of these tissues. The proportion of these tissues in relation to body weight appears to be positively correlated with intake. It has been suggested that proportion of visceral organ during unrestricted intake could be related to inherent impetus for growth (Webster 1993).

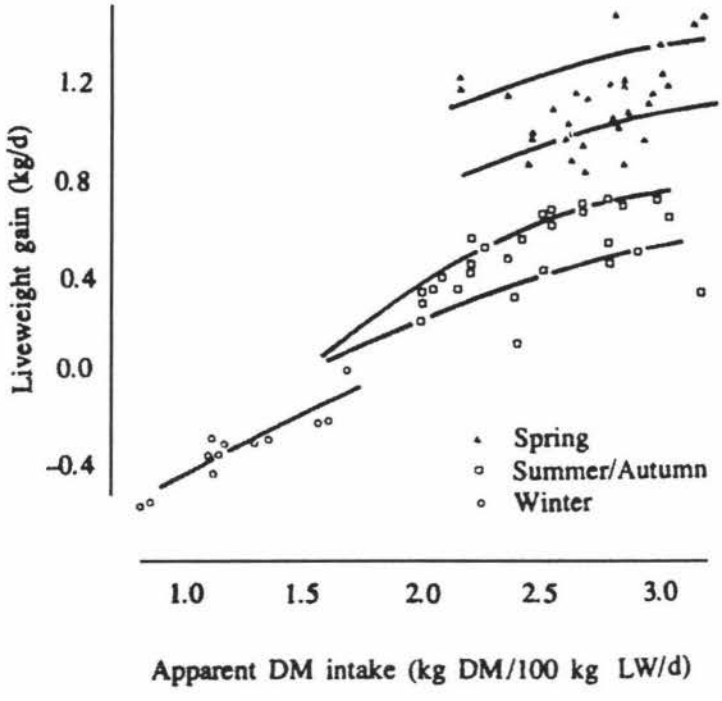
*2.3.2. Intake*

In discussing the relative intakes of cattle of different liveweights, values of intake relative to live weight (kg intake/100kg LWT/d) will be used. The relationship between liveweight gain and intake has been intensively studied under New Zealand pastoral systems (Nicol and Nicoll 1987; Morris *et al.* 1993; Aranda-Osorio *et al.* 1996; Realini *et al.* 1999). Nicol and Nicoll (1987) illustrated the seasonal relationship between apparent DM intake and liveweight gain from

four sources (Figure 2.6). Renand *et al.* (1992) discussed the relative intakes of different breeds summarised from 3 different experiments. They found that voluntary feed intakes (intake/metabolic liveweight unit) ranged from –5% to +9% for different breeds in relation to that of Charolais. Angus had 4%, and Hereford had 1% higher intakes than Charolais.

Realini *et al.* (1999) found 26 month old steers weighing approximately 490kg required 1.02 and 1.50kg DMI/100kg LWT/d to achieve gains of 0.32 and 1.10kg/d on spring pasture of 5 and 10cm sward surface height (SSH), respectively, with a DM digestibility of approximately 68%. Aranda-Orsorio *et al.* (1996) found steers achieving 0.71kg/d ADG over 203 days required 1.86 and 1.62kg OMI/100kg LWT/d in spring and the subsequent autumn, respectively. Morris *et al.* (1993) investigated high (15cm) and low (6cm) grazing heights of pasture and found Friesian bulls of 172kg growing at 0.38 and 1.36kg/d consumed 2.2 and 2.8kg OMI/100kg LWT/d in autumn, respectively. Charolais x Angus steers (223kg) grazing the same pastures required 1.3 and 2.1kg OMI/100kg LWT/d to achieve –0.42 and 1.25kg/d growth, respectively. In spring, the bulls, now 288kg, required 3.4 and 3.8kg OMI/100kg LWT/d to reach growth rates of 1.21 and 1.68kg/d, while the steers (323kg) required 2.3 and 2.4kg OMI/100kg LWT/d to achieve 0.67 and 1.68kg/d, respectively. The values from these three trials further demonstrate the relationship between intake and liveweight gain.

Figure 2.6. Relationship between apparent DM intake and liveweight gain of growing beef cattle at pasture from four studies (Nicol and Nicoll 1987)




Animal performance usually increases at a steadily declining rate toward a maximum value as herbage allowance increases (Hodgson 1984). Similarly as the pasture mass being grazed declines below critical heights (and mass), intake and therefore animal performance declines. Pasture allowance and post-grazing mass both have curvilinear relationships with growth rate of cattle at pasture. Nicol and Nicoll (1987) in summarising the four studies shown in Figure 2.6, produced tables showing the average daily gain achieved at different pasture allowance and post-grazing mass levels (Table 2.2).

Table 2.2. Beef cattle growth rates (kg/d) at different pasture allowance and post-grazing pasture mass levels (Nicol and Nicoll 1987)

| | Pasture Allowance (kg DM/100kg LWT/day) | | | | |
|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 |
| Spring | 0.42 | 0.85 | 1.11 | 1.20 | 1.20 |
| Sum/Aut | 0.00 | 0.32 | 0.52 | 0.64 | 0.66 |
| Winter | -0.64 | -0.20 | - | - | - |
| | Post-Grazing Pasture Mass (kg DM/ha) | | | | |
| | 750 | 1000 | 1500 | 2000 | 2500 |
| Spring | 0.53 | 0.77 | 1.04 | 1.15 | 1.15 |
| Sum/Aut | 0.02 | 0.17 | 0.38 | 0.50 | 0.60 |
| Winter | -0.50 | -0.10 | 0.10 | - | - |

Scott *et al.* (1976) discussed the factors leading to differences between liveweight gains in cattle in autumn compared with spring and suggested that numerous factors such digestibility, stage of maturity and proportion of dead matter of the sward can alter the performance of an animal on different pastures. They found that autumn pasture had low soluble carbohydrate and cellulose concentrations and high crude protein concentrations than spring pasture and suggested that the high crude protein levels could have an influence on the maintenance requirements of animals in autumn due to the high cost of excreting excess nitrogen. Geenty and Rattray (1987) stated that soluble carbohydrate levels of herbage are low in autumn and high in spring and this may affect animal performance by altering rate of fermentation, rate of passage and proportion of volatile fatty acids in the rumen.

Differences in response to pasture intake may be due to factors such as digestibility, metabolisable energy and crude protein content, botanical

composition and stage of maturity as discussed above and in section 2.3.1. Breed differences exist in terms of voluntary feed intake with feed intake per unit metabolic liveweight being lower in European breeds than in British breeds. Conversion of pasture intakes into kg intake/100kg LWT/d allows comparison between animals of different age and size. There appears to be relatively consistent results in the studies reviewed with increased liveweight gains requiring increased pasture intake. Post-grazing pasture mass and pasture allowance, both have a positive correlation with liveweight gain throughout the year.

*2.3.3. Feed Conversion Efficiency*

To make comparisons between individuals or groups of animals, many researchers have considered feed intake and production outputs over a limited part of the production cycle, and expressed feed efficiency using an index which combines intake (input) with production (output) (Archer *et al.* 1999). They concluded that it was not possible to make uniform recommendations from a single index. However, gross feed efficiency (GFE), or it's inverse, feed conversion ratio (FCR) is the most widely used index and gross efficiency is both phenotypically and genotypically correlated with aspects of production (Archer *et al.* 1999). GFE is defined as unit production/unit feed eaten while FCR is units feed eaten/unit production (Archer *et al.* 1999).

Veerkamp and Emmans (1995) in a review of genetic variation of efficiency in dairy cows, suggested that there are probably no large genetic differences among cows in the ability to digest or metabolise a given feed at a constant level of feeding. However, Archer *et al.* (1999) suggested that numerous studies indicate that genetic variation exists in GFE or in FCR of growing cattle measure on a time-constant basis. They also state that there is a lack of understanding of the mechanisms responsible for the observed variation in feed efficiency. Andersen (1978) found genetic correlations of –0.95±0.30, 0.46±0.14, 0.27±0.17 and –

0.53±0.19 for FCR with average daily gain, dressing percentage, lean to bone ratio and lean to fat ratio.

Heritability estimates for feed conversion ratios in 8 studies summarised by Veerkamp and Emmans (1995) ranged between 0.16 and 0.46. Arthur *et al.* (1999) calculated estimates heritability of 0.59±0.07, 0.41±0.08 and 0.31±0.09 for feed intake, average daily gain and feed conversion ratio respectively.

Webster (1985) stated that the ratio of fat:lean in the liveweight gain has a significant effect on feed conversion efficiency, with increased fat in the gain leads to poorer feed conversion efficiency. Differences in mature size have little influence on feed conversion efficiency (Veerkamp and Emmans 1995). Feed conversion ratio of growing cattle is largely a function of maturity patterns (Salmon *et al.* 1990). Richardson *et al.* (1996) found a small but significant difference in digestibility of feed between cattle with high and low feed efficiencies. Herd *et al.* (1993) found in sheep selected for weaning weight, that those with high weaning weights digested 1.8% more dietary organic matter than those selected for low weaning weight, and suggested that digestibility may be associated with genetic differences in performance. Galbraith and Topps (1981) suggested that bulls are more efficient at converting feed than steers with a likely difference of 10% (range of studies summarised was 0-15%). Renand *et al.* (1992) compared GFE of different breeds in summarised from 3 experiments. They found that relative to Charolais, Angus were 11% less efficient and Hereford 2% less efficient. GFE's of different breeds ranged from –12% to +4% relative to that of Charolais. They stated that GFE is a complex criterion depending on simultaneous variations in maintenance requirements, feed intake and muscle growth capacity, as well as the conditions of the trial involved, and that a close relationship between feed efficiency and lean growth rate was found. They also stated that the relative influence that maintenance requirement and muscle growth capacity of the individual is dependant on feeding with

maintenance requirements playing a larger role under low feeding levels and muscle growth capacity under high feeding levels.

Morris *et al.* (1993) obtained GFE's of 0.10, 0.15 and 0.27kg ADG/kg OMI in autumn and 0.13, 0.19 and 0.14kg ADG/kg OMI in the subsequent spring for Friesian bulls on approximately 4, 8 and 12cm high pastures, respectively. Charolais-cross steers achieved GFE's of 0.11 and 0.27kg ADG/kg OMI on 8 and 12 cm pastures in autumn, respectively, and 0.09, 0.17 and 0.21kg ADG/kg OMI in the subsequent spring. GFE generally increased with increased pasture height grazed by the cattle. From data of Aranda-Orsorio *et al.* (1996) it was calculated that steers gaining an average 0.71kg/d over 203 days achieved a GFE of 0.11kg ADG/kg OMI. Realini *et al.* (1999) found that 26-month old steers growing 1.10kg/d and 0.32kg/d achieved GFE's of 0.15 and 0.06kg ADG/kg DMI respectively. Earlier work by Marsh (1975) found no difference between GFE's of Friesian cattle on autumn and spring pastures over two years with values of 0.13 and 0.12kg ADG/kg DMI in the two autumns 0.12 and 0.13kg ADG/kg DMI in the two springs. Bailey *et al.* (1966) found bulls were significantly ($P<0.01$) more efficient than steers over 112 days on a feedlot with GFE's of bulls and steers being $0.13\pm0.06$ and $0.11\pm0.06$kg ADG/kg DMI respectively.

In summary, gross feed efficiency is measured as production to intake ratio. The inverse to this is feed conversion ratio. Review of the literature of this area can be difficult due to researchers, at times, confusing use of the term feed efficiency. For this reason it was appropriate to define and use the terms gross feed efficiency and feed conversion ratio. It appears that feed efficiency may be affected by factors such as fat to lean ratio of the growth and hence, stage of maturity, maintenance requirements, and may in part be due to differences in the animals ability to digest certain feeds. Breed differences are apparent in GFE with European breeds being more efficient than British breeds over a set body weight range. Feed efficiency appears to be strongly genetically correlated with

liveweight gain (-0.95 for FCR and liveweight gain in one study), and moderately heritable. GFE's of between 0.10 to 0.27kg ADG/kg OMI were found in the studies reviewed of beef cattle at pasture. Several studies found bulls were more efficient at converting food to gain than steers. There appears to be a good relationship between feed efficiency and liveweight gain in the studies examined, however no studies were found that examined feed conversion efficiency differences in cattle without the confounding effect of different pasture intakes.

## 2.4. Summary

The efficiency of any beef cattle finishing system is affected by the growth rate potential of the individual animals in that system. Faster growing animals allow earlier achievement of targeted carcass weights at slaughter, at lower costs in terms of feed maintenance requirements. Most of the traits examined as potential determinants of growth-rate differences between animals have moderate to high heritability estimates. Identifying the relative influence of each trait on growth could be important to allow possible selection for these traits and therefore improvement in the efficiency of beef finishing systems.

From the material in this review it is apparent that the inherent ability of an animal to grow is affected by numerous factors. There is certainly evidence that stage of maturity and potential mature weight play an important part in the differences in growth potential between animals. Similarly differences in potential growth rate of different breeds and sex and castration types exist. Less clear is the effect of differences in voluntary feed intake, feed efficiency, temperament and chronic stress on variation in growth rate. Studies have examined these in relation to differences between groups of animals, but few have examined the effects of these on the differences between individual animals run together. This is due in part to the difficulty in measurement of these traits on an individual animal basis under pastoral farming systems.

# CHAPTER 3. INVESTIGATIONS INTO VARIATION IN GROWTH PERFORMANCE OF CATTLE AT PASTURE.

## 3.1 Introduction

Many factors may be responsible for variation in the growth rate of similar cattle when run together in pastoral farming situations including differences in appetite, efficiency of feed utilization, mature weight and temperament. These factors may broadly be categorised as nutritional, physiological, behavioural or genetic traits. The experiment reported here evaluated some of these traits in order to seek a better understanding of the influences on variation in growth rate in similar cattle run together at pasture.

Recent research results for beef cattle under pastoral farming situations have suggested a relationship between temperament and animal live weight gain, with calmer animals exhibiting higher live weight gains (Fordyce *et al.* 1985; Fordyce *et al.* 1988). This relationship has also been observed in feedlot cattle (Voisinet *et al.* 1997a). Social interaction will occur within any group of cattle and may cause chronic stress for some animals. Muscle glycogen levels may be a potential indicator of chronic stress. An animal with less muscle glycogen suggests higher adrenaline production and therefore may indicate stressful animal interactions within the grazing group for that animal. Mature weight is an important factor in relation to growth as cattle growing towards a higher mature weight will normally grow faster up to the time that weight is attained (Kirton and Morris 1989). Metabolic rate may influence the relative growth rates of animals as a higher metabolic demand may lead to a higher maintenance requirement and a lower growth rate at the same body weight and level of intake.

The objectives of this study were therefore:

To examine the relationships between the growth rate and estimates of voluntary feed intake, feed conversion efficiency, temperament, susceptibility to chronic (longer-term) stress, indices of mature weight and indices of metabolic rate within groups of similar cattle run together.

## 3.2. Materials and Methods

### *3.2.1. Animals and Experimental Design*

Sixty Hereford x Angus cross male cattle (30 bulls and 30 steers) were purchased in March 1997 as weaners (approximately 5 months of age) for this experiment. The cattle were selected from the same initial herd of animals with a random half being castrated in November 1996 (d-121). The cattle were allocated in July 1997 (d112) to either the fastest growing two-thirds or slowest growing third (Restricted-Slow Group (RS)) at an age of about 9 months, based on their growth rate over a 100 day period commencing from 26 March 1997 (d0) to 4 July 1997 (d100), which was 14 days post after weaning and transportation to the Massey University research farm. The fastest growing two-thirds were randomly allocated between the Fast group (F) and Restricted-Fast (RF) groups. Restriction of growth of the RF and RS treatment groups commenced on d112.

The target slaughter liveweight for all treatment groups was approximately 550kg. Treatment group F cattle (10 bulls, 10 steers) were grown rapidly to achieve this weight (target 550kg) at approximately 16-18 months of age, (February (d328) and April 1998 (d391) for bulls and steers, respectively), while treatment group RS was fed a restricted ration of pasture and hay (during winter) in order to achieve a similar weight at 25 months of age. Treatment group RF was also managed to reach the target weight at 25 months, but they had to be restricted to a greater extent over some periods in order to counter their greater growth potential. This extra restriction occurred for periods of one month in July 1997 (9 months of age), February 1998 (16 months) and September 1998 (23 months).

The trial was therefore a 3 x 2 factorial with 3 growth path groups and 2 castration groups (bulls vs. steers) as illustrated in Table 1. The timetable of the experiment is shown in Appendix 1.

Table 3.1. Number of animals within Growth Path (F v RF v RS) x Castration (Bull v Steer) sub-groups

| Castration Status | Bulls | Steers | Total |
|---|---|---|---|
| Growth Path | | | |
| Fast (F) | 10 | 10 | 20 |
| Restricted-Fast (RF) | 10 | 10 | 20 |
| Restricted-Slow (RS) | 10 | 10 | 20 |
| Total | 30 | 30 | 60 |

The cattle were run on the Animal Research Unit at Massey University under normal farm management practices. All cattle were run together until 9 months of age and were fed the maximum possible during this period within normal farm constraints.

*3.2.2. Management.*

The cattle were rotationally grazed on 6 paddocks of perennial ryegrass (*Lolium perenne*) – white clover (*Trifolium repens*) pasture totalling 23ha until April 1998. Pasture mass was assessed using a Rising Plate Meter (Ashgrove Pastoral Products, Palmerston North, New Zealand) and sward surface height measured using an Automatic Sward Stick (Jenquip, Feilding, New Zealand) (section 3.2.3.). Pasture mass averaged 1940kg DM/ha, with averages ranging from 1381 – 3175kg DM/ha, over the 12 months that the cattle remained on this area.

Post-grazing residuals averaged 1216kg DM/ha, ranging from 915-1530kg DM/ha. Sward surface height averaged 7.34cm (range 3.55-15.03cm) and 2.97cm (range 1.19 – 5.17cm) for pre- and post grazing measurements. Hay was fed as a supplement in the winter of 1997 to the RF and RS treatment groups at maintenance levels. Intake measurements (described in 3.2.4.) were conducted on 4 separate paddocks of similar pasture cover and type to those the groups came from.

From April 1998 the remaining 40 RF and RS treatment groups were fed to achieve restricted liveweight gain (less than 0.5kg/day) including a period of 4 months (June – September) when the cattle were fed a diet of hay and pasture at maintenance levels. Restriction of liveweight gain was also achieved using rotational grazing on pastures that had previously been grazed by other groups of stock. This was done to achieve a second slaughter date of 16-23 November 1998 (d600 and d607 for the bulls and steers, respectively) at similar liveweights as the F treatment groups.

### *3.2.3. Pasture Measurements*

Pre- and post-grazing pasture sward surface heights were measured using an Automatic Sward Stick (50 readings per paddock) following the method described by Barthram (1986) for the HFRO sward stick, and pasture mass of the grazing area (50 readings per paddock) was estimated using a rising plate meter on a monthly basis (Earle and McGowan 1979).

### *3.2.4. Animal Measurements*

Fasted liveweights (18 hours from 2pm to 8am) were collected at the beginning of the trial (March 1997, d0), before and after each intake period (June 1997, October 1997, February 1998 and October 1998)) and pre slaughter. Unfasted liveweights (fresh off pasture) were taken at approximately monthly intervals in the afternoon (approximately 2pm) to standardise gutfill. Withers height (cm height at withers) was measured immediately prior to each intake period in June

1997(d83), October 1997 (d209), February 1998 (d307) and October 1998 (d580).

Herbage intakes were estimated for all cattle in the F and RS treatment groups (10 bulls and 10 steers each treatment group) and half the cattle (5 bulls and 5 steers) of the R treatment group, at approximately 9, 14,17 and 25 months of age (June and November 1997, February and October 1998), using chromium intraruminal controlled release capsules (CAPTEC Large Cattle Chrome Controlled Release Capsules, Captec (New Zealand) Ltd, Auckland). The capsules were inserted on Intake Day 0 (d83, 209, 307 and 580) after the cattle had been held for 16 hours in the yards, and at least three daily individual faecal samples per animal were collected over each of two 5-day periods starting on Intake Days 7 and 14 (d90-100, d216-226, d314-324 and d587-597 respectively). The faeces were oven-dried at approximately 70°C to a constant weight (Aranda-Osorio *et al.* 1996). Herbage samples were handplucked (Aranda-Osorio *et al.* 1996) to simulate grazing during each 5-day intake period for in vitro analysis for digestibility (Roughan and Holland 1977).

### *3.2.5. Animal Response Measurements*

The following temperament observations were recorded immediately prior to each intake period in June 1997 (d82), November 1997 (d208), February 1998 (d306) and October 1998 (d579) as measures of fear and anxiety.

Each animal was left standing on the weighing platform of a fixed period of time (20 seconds) during weighing and the number of steps or movement of front or back feet were counted during that period. The weighing platform had enclosed sides, but the animal could see out the front. The same assessor was used for each observation and they observed the animal's movements from behind the weighing crate through a barred gate. This provided a ranking of their anxiety when isolated from the herd. Their reaction to being isolated over

the 20 seconds was also scored using the 8-point scale of Hearnshaw and Morris (1984) as follows:

1 = Calm and still.

2 = Still but showing slight agitation (eye movements).

3 = Slight head movements.

4 = Slight movement of head, front feet, swishing tail.

5 = Eyes show slight panic, movement of head, front feet.

6 = All feet move, head up.

7 = Moves considerably or quivers, moos and may jump.

8 = Full of panic, attempts to climb out, may bellow.

Scoring using the 6-point scale of Morris *et al.* (1994), was assessed as the animal moved off the weighing platform and into an empty yard approximately 30m long x 15m wide while the assessors remained still. The scale was:

1 = Walks at leisurely pace.

2 = Trots and is slightly nervous.

3 = Nervous, runs, baulks or turns.

4 = Jumps with side steps.

5 = Upset, with prancing sudden side steps.

6 = Extremely disturbed.

When the animal had settled at a distance of at least 15m away and was facing the assessor, it was approached at a constant speed (slow to moderate walking pace) until it turned to move away. This flight distance was estimated with the aid of one metre markings on the railings of the yards. When the animals had settled again, a gate into a large paddock area at the opposite end of the yard was opened and the animals speed was again assessed using the above 6-point scoring system (Morris *et al.* 1994).

The above scores, flight distance and number of steps recorded were each adjusted to a common range with a minimum of 1 and maximum of 24. These

adjusted values were then summed to give a maximum possible value of 144, then converted to a 0-10 range by dividing by 14.4 to give an overall temperament index which could then be analysed as described in section 3.2.8

### *3.2.6. Muscle Glycogen and Plasma Components*

On 16th July 1997 (d112), 13th November 1997 (d232) and 14th January 1998 (d294) muscle biopsy and blood samples were taken from the cattle. Blood sampling was by venipuncture of the tail vein using a heparinised vacutainer. The plasma samples obtained from centrifugation at 2500rpm for 20 minutes were frozen for subsequent assay to determine levels of glycogen, cortisol, glucose, non-esterified fatty acids (NEFA), creatine kinase and lactate.

A biopsy sample was taken from the *M. longissimus lumborum* following a method based on that of Tarrant and McVeigh (1979).

The cattle were restrained in a head bail and sedated using a low dose of Rompun (Bayer New Zealand Ltd., Auckland, New Zealand). A patch on one side of the backbone over the longissimus muscle was shaved, disinfected and a local anaesthetic (Lignocaine, Ethical Agents Ltd., Auckland, New Zealand) injected. A muscle sample of approximately 300mg was taken using a percutaneous sampling tool (5mm internal diameter) developed by scientists at AgResearch and the wound was treated with antibiotic powder and a long-acting antibiotic was administered intramuscularly to the anterior neck region

### *3.2.7. Slaughter Procedures*

The cattle were weighed full on the farm prior to being trucked approximately 20km to Manawatu Beef Packers Ltd., Feilding, where slaughter and dressing was according to normal commercial conditions.

Carcasses were weighed and carcass length was measured on both sides from the distal end of the tarsal bones to the midpoint of the cranial edge of the first rib (Purchas 1990). Kidney and pelvic fat from both sides was weighed. Liver and heart weights were recorded. After overnight chilling at 1-3°C, each carcass was quartered between ribs 12 and 13, and the fat depth over the *M. longissimus* was

measured at a point ¾ the length of the *M. longissimus* from the chine bone end (AMSA 1977). During the boning of the carcass sides, the left femurs were collected and trimmed prior to their lengths and weights being recorded.

### *3.2.8. Statistical Analysis.*

Data were analysed using SAS (1985). Levels of significance and least-squares means were calculated using the GLM procedure. Withers heights were adjusted to a constant liveweight at the time of measurement and carcass composition characteristics and organ weights were adjusted for carcass weight, by covariance analysis. Feed conversion efficiency was calculated as the ratio of empty liveweight gain (Gross feed efficiency, GFE) during the intake period (18 days) to OM intake. Temperament data was analysed using a single index as described in section 3.2.5. All data were correlated with full and fasted daily liveweight gains for the periods preceding the measurement dates. These periods were March 1997-June1997 (LWG1), July1997-October1997 (LWG2), November1997- January 1998 (LWG3) and February 1998-October 1998 (LWG4). Data were also correlated with liveweight gain up to the first slaughter at approximately 16 months of age, in February 1998 (LWG16M) and with liveweight gain until slaughter of the individual (LWGSLT). Correlation coefficients were calculated using residuals of individual animals from the mean of their sex by treatment group, rather than raw values. These residuals were obtained from general linear models containing sex and treatment as class variables, a sex by class interaction term and a covariate were appropriate as outlined above. Correlation analyses using the residuals rather than unadjusted values allowed analysis of data from all 60 cattle at once.

## 3.3. Results

### *3.3.1. Growth.*

Figure 3.1 illustrates the growth path achieved by the F, RF and RS cattle from d-121 to final slaughter at d607. Table 3.2 shows liveweights at d0 (start of the

trial), d100 (end of the 100 day growth assessment period), d324 (final weight before treatment F bull slaughter) and d597 (final weight before treatment RF and RS slaughter). Average daily gains to d324 and d597 are also shown.

Figure 3.1. Mean (±SE) liveweights of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls and steers.

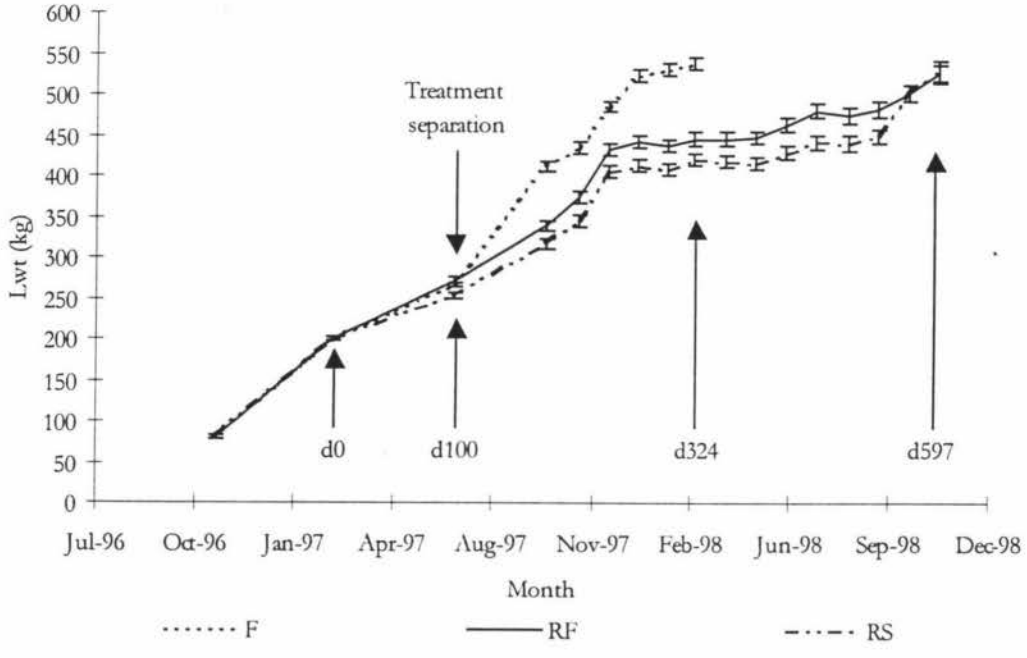
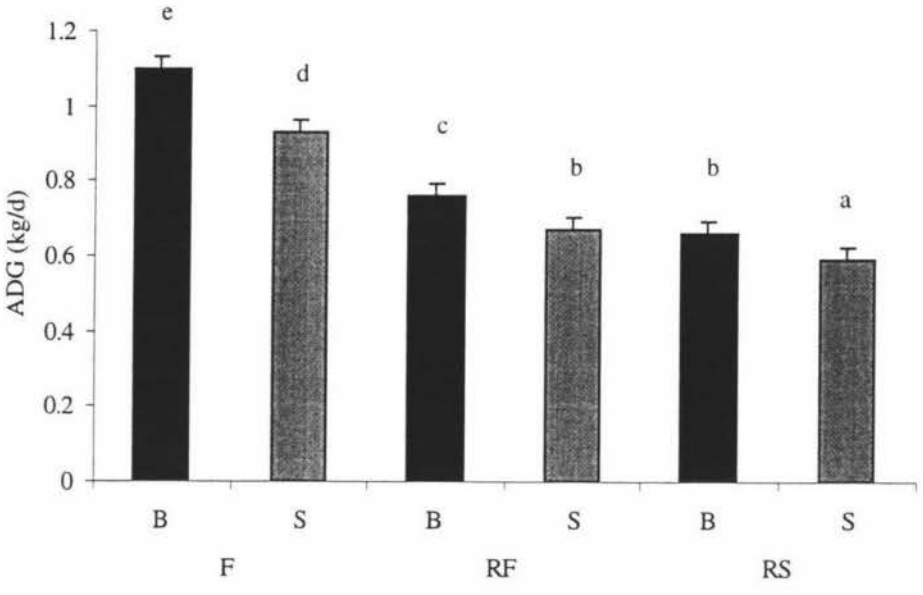


Table 3.2. Least-squares means (±SE) for full liveweight (kg) and average daily gain (kg/d) of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S). Means within rows without common superscript letters were significantly different at P<0.05.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| Day | F | RF | RS | P Value | B | S | P Value |
| Full Liveweight (kg) | | | | | | | |
| d0 | 205.1±4.0 | 207.2±4.0 | 205.4±4.0 | NS | 207.7±3.3 | 204.0±3.3 | NS |
| d100 | 266.2±4.3$^{b}$ | 270.5±4.3$^{b}$ | 252.9±4.3$^{a}$ | 0.05 | 270.7±3.5 | 255.7±3.5 | 0.005 |
| d324 | 532.3±7.7$^{c}$ | 437.1±7.7$^{b}$ | 408.0±7.7$^{a}$ | 0.001 | 479.4±6.3 | 438.8±6.3 | 0.001 |
| d597 | - | 523.6±11.7 | 527.4±11.7 | NS | 545.4±11.7 | 505.5±11.7 | 0.05 |
| ADG kg/d) | | | | | | | |
| d0 – 324 | 1.01±0.02$^{c}$ | 0.71±0.02$^{b}$ | 0.63±0.02$^{a}$ | 0.001 | 0.84±0.01 | 0.73±0.01 | 0.001 |
| d0 - 597 | - | 0.53±0.02 | 0.54±0.02 | NS | 0.56±0.02 | 0.51±0.02 | 0.05 |

The F treatment group cattle achieved pre-slaughter liveweights of 550±13kg and 522±8kg for the bulls and steers, respectively by 16-18 months of age, and achieved average daily gains of 1.10±0.03 and 0.93±0.03kg/d (P<0.001) from d0 to final weight before slaughter at d328 (17 February 1998) and d391 (21 April 1998), respectively. This represents an 18% higher average daily gain by bulls over that achieved by the steers. These cattle were fed the maximum possible under normal farm constraints throughout the entire period from 9 months of age. Figure 3.2 illustrates the average daily gains achieved prior to the F bull slaughter by the 6 sub-groups.

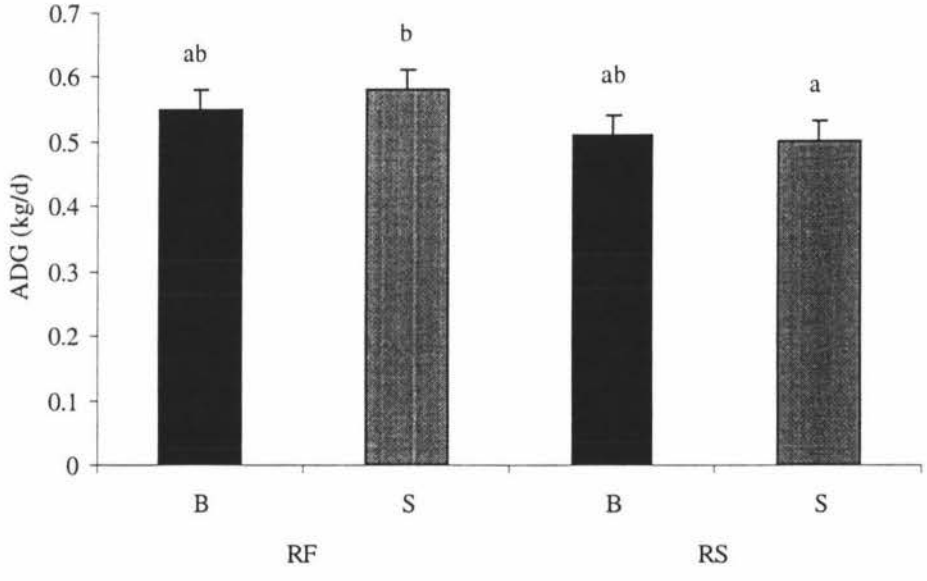
Figure 3.2. Least-squares means (±SE) for average daily gains from d0 to d324 of the bulls (B) and steers (S) of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups (kg/d). Bars without common superscript letters were significantly different at $P<0.05$.




The Treatment RF and RS groups were run together with target pre-slaughter liveweights similar to the F treatment group cattle at approximately 25-26 months of age. The liveweights of the RF and RS bulls averaged 544±13kg and 541±13kg (NS) at slaughter on d600 (16 November 1998) while the RF and RS steers averaged 527±19 and 515±19kg (NS) at slaughter on d607 (23 November 1998). No significant differences existed between the pre-slaughter liveweights of any treatment sub-group. The RF and RS treatment groups average daily gains from d0 to slaughter on the 16 November (bulls) and 23 November (steers) 1998 were 0.56±0.02kg LWG/d and 0.51±0.02kg LWG/d (NS), respectively. Figure 3.3 illustrates the lifetime average daily gains achieved by the 4 sub-groups within the RF and RS treatment groups. It is important to note, that although the RS and RF groups were run together from d112 on a restricted

diet, the RF treatment group repeatedly grew faster over time and on 3 occasions (see section 3.2.1.) had to be further restricted over the RS treatment group to allow the RS cattle to catch up. This was done to achieve similar slaughter weights at approximately 25 months of age.

Figure 3.3. Least-squares means (±SE) for average daily gains from d0 to d597 of the bulls (B) and steers (S) of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups (kg/d). Bars without common superscript letters were significantly different at $P<0.05$.




*3.3.2. Organic Matter Intake and Feed Conversion Efficiency*

The organic matter intakes are shown in Table 3.3. During the d90-100 intake measurements all 60 cattle were fed *ad libitum* pasture. The organic matter intakes of the F treatment group cattle were significantly lower than the RF and RS cattle during the d90-100 period. This is likely to be a random effect due to the subsequent allocation of treatments on d112. During the d314-324 intake period the RS cattle (4.20±0.20kg OMI/hd/d) had significantly lower intakes ($P<0.05$) than the F cattle (4.71±0.20kg OMI/hd/d) although the RF cattle were

not significantly different from either (4.23±0.20kg OMI/hd/d). During the d587-597 intake period the RF and RS treatment groups were grazed separately with the RF cattle having higher pre-grazing pasture allowances (2403 and 3455kg DM/ha for week 1 and 2, respectively) than the RS cattle (1995 2403kg DM/ha for week 1 and 2, respectively).

The intakes of bulls were significantly higher than steers during the d314-324 and d587-597 intake periods, but were not significantly different at either the d90-100 or d216-226 periods. Liveweight gains during the d314-324 period were not significantly different (0.07±0.12 vs. 0.06±0.12kg LWG/d for bulls and steers, respectively). Liveweight gains were 1.41±0.21 vs. 0.88±0.21kg LWG/d for the bulls and steers during the d587-597 intake period although the difference was again not significant due to large variation.

Table 3.3. Least-squares means (±SE) for organic matter intakes of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S) during the intake measurement periods d90-100, d216-226, d314-324 and d587-597 (kg OMI/hd/d). Means within rows without common superscript letters were significantly different at P<0.05.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| Intake period | F | RF | RS | P Value | B | S | P Value |
| d90-100 | 3.78±0.12[a] | 4.27±0.15[b] | 4.22±0.14[b] | 0.05 | 4.06±0.12 | 4.12±0.11 | NS |
| d216-226 | 5.06±0.17 | 5.21±0.25 | 5.05±0.18 | NS | 5.15±0.17 | 5.07±0.16 | NS |
| d314-324 | 4.71±0.15[b] | 4.23±0.20[ab] | 4.20±0.15[a] | 0.05 | 4.69±0.14 | 4.07±0.14 | 0.005 |
| d597-597 | - | 6.20±0.23 | 4.87±0.17 | 0.001 | 5.97±0.20 | 5.10±0.20 | 0.01 |

Steers were significantly less efficient at converting food to gain (kg LWG/kgOMI) than bulls (0.18±0.01 vs. 0.24±0.01kg LWG/kg OMI, P<0.001) during the d90-100 intake period when all 60 cattle were fed at *ad libitum* levels (Table 3.4.). No significant differences were found between the gross feed

efficiencies of bulls and steers during any of the subsequent intake measurement periods.

The RS treatment group was also less efficient than both the RF and F treatment groups during the d90-100 intake period (0.16±0.02 vs. 0.23±0.02 vs. 0.23±0.02kg LWG/kg OMI respectively, $P<0.005$). The F treatment group was significantly more efficient than the RS and RF groups during the d216-226 intake measurement period, and remained significantly more efficient at feed conversion than the RS treatment group during the d314-324 measurement, however the difference between the F and RF groups was not significant ($P<0.10$) at this time.

Table 3.4. Least-squares means (±SE) for gross feed efficiency of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S) following capsule insertion on days 83, 209, 307 and 580 (kg LWG/kg OMI). Means within rows without common superscript letters were significantly different at $P<0.05$.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| Intake period | F | RF | RS | P Value | B | S | P Value |
| d90-100 | 0.23±0.01$^{b}$ | 0.23±0.01$^{b}$ | 0.16±0.02$^{a}$ | 0.005 | 0.24±0.01 | 0.18±0.01 | 0.001 |
| d216-226 | 0.32±0.02$^{b}$ | 0.20±0.03$^{a}$ | 0.24±0.02$^{a}$ | 0.001 | 0.23±0.02 | 0.27±0.02 | NS |
| d314-324 | 0.18±0.02$^{b}$ | 0.10±0.04$^{ab}$ | 0.09±0.02$^{a}$ | 0.01 | 0.11±0.02 | 0.12±0.03 | NS |
| d597-597 | - | 0.21±0.04 | 0.29±0.03 | NS | 0.28±0.04 | 0.21±0.04 | NS |

### *3.3.3. Temperament*

Temperament was assesses in several ways throughout this trial. Table 3.5 shows the resulting temperament indices from measurements taken on the 4 measurement days (d82, 208, 306 and 579). These indices were calculated from the individual assessments made as described in section 3.2.5. No significant differences were found between temperaments of bulls and steers on any occasion. The RF treatment group was significantly calmer than the F and RS

groups on d208 and than the RS group on d 579. On d306 the RF treatment group tended to be calmer (1.95±0.33) than the F (2.77±0.33) and the RS (2.79±0.33) however the difference only approached significance (P<0.1).

Table 3.5. Least-squares means (±SE) for temperament indices (0-10 scale as described in section 3.2.5.) of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S) at d82, 208, 306 and 579. Means within rows without common superscript letters were significantly different at P<0.05.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| Day | F | RF | RS | P Value | B | S | P Value |
| d82 | 2.88±0.34 | 2.33±0.34 | 2.77±0.34 | NS | 2.75±0.28 | 2.57±0.28 | NS |
| d208 | 3.28±0.31$^{b}$ | 2.28±0.31$^{a}$ | 3.28±0.31$^{b}$ | 0.05 | 2.81±0.25 | 3.08±0.25 | NS |
| d306 | 2.77±0.33 | 1.95±0.33 | 2.79±0.33 | NS | 2.50±0.27 | 2.50±0.27 | NS |
| d579 | - | 1.09±0.19$^{a}$ | 1.94±0.19$^{b}$ | 0.005 | 1.35±0.19 | 1.67±0.19 | NS |

Blood cortisol and muscle glycogen levels are shown in table 3.6. There were highly significant differences (P<0.001) between cortisol levels of bulls and steers on all occasions. The cortisol levels of the bulls were less than 50% of that of the steers except at slaughter. No differences existed between the sexes for muscle glycogen levels. There were no significant differences between the treatment groups for cortisol or muscle glycogen levels on days 112 and 232. On d294 the F treatment group exhibited significantly higher cortisol levels (23.1±1.6ng/ml vs. 14.9±1.6 and 15.7±1.6ng/ml for the RF and RS treatment groups respectively) and muscle glycogen levels (22.26±0.89 vs. 16.87±0.89 and 16.08±0.896mg/g wet weight, for the RF and RS treatment groups respectively).

Table 3.6. Least-squares means (±SE) for cortisol levels (ng/ml) in the blood and *M. Longissimus* muscle glycogen levels (mg/g wet weight) of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S) at d112, 232, 294 and at slaughter (cortisol only). Means within rows without common superscript letters were significantly different at $P<0.05$.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| Day | F | RF | RS | P Value | B | S | P Value |
| Cortisol | | | | | | | |
| d112 | 16.9±1.8 | 14.5±1.8 | 19.3±1.8 | NS | 9.3±1.5 | 24.5±1.5 | 0.001 |
| d232 | 23.2±1.8 | 21.9±1.8 | 21.5±1.8 | NS | 13.8±1.5 | 30.6±1.5 | 0.001 |
| d294 | 23.1±1.6$^{b}$ | 14.9±1.6$^{a}$ | 15.7±1.6$^{a}$ | 0.001 | 11.7±1.3 | 24.1±1.3 | 0.001 |
| At slaughter | 25.5±3.1$^{a}$ | 35.5±3.1$^{b}$ | 44.5±3.1$^{c}$ | 0.001 | 25.4±2.6 | 44.9±2.6 | 0.001 |
| Muscle Glycogen | | | | | | | |
| d112 | 16.68±1.00 | 16.26±1.00 | 17.38±1.00 | NS | 17.78±0.81 | 15.77±0.81 | NS |
| d232 | 20.36±1.17 | 19.62±1.17 | 23.18±1.17 | NS | 20.27±0.96 | 21.83±0.96 | NS |
| d294 | 22.26±0.89$^{b}$ | 16.87±0.89$^{a}$ | 16.08±0.89$^{a}$ | 0.001 | 18.23±0.73 | 18.57±0.73 | NS |

### *3.3.4. Measures of Indicators for Mature Weight and Metabolic Rate*

Weight-adjusted heights (Table 3.7) were not significantly different between sexes on d83, however, they were significantly lower for bulls than steers on days 209 (1400±5 vs. 1419±2mm, $P<0.05$), 307 (1439±6 vs. 1463±6mm, $P<0.01$) and 580 (1490±8 vs. 1523±6mm, $P<0.01$). This indicates that the bulls were heavier at a given height. Weight-adjusted heights were not significantly different due to treatment at any time.

Table 3.7. Least-squares means (±SE) for weight-adjusted height (mm height at withers) of the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S) at d90-100, 209, 307 and 580. Means within rows without common superscript letters were significantly different at P<0.05.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| Day | F | RF | RS | P Value | B | S | P Value |
| d82 | 1292±6 | 1288±3 | 1290±3 | NS | 1286±3 | 1294±3 | NS |
| d208 | 1400±10 | 1414±7 | 1416±8 | NS | 1400±5 | 1419±2 | 0.05 |
| d306 | 1447±10 | 1455±7 | 1451±9 | NS | 1439±6 | 1463±6 | 0.01 |
| d579 | - | 1513±8 | 1500±8 | NS | 1490±8 | 1523±6 | 0.01 |

Carcass characteristics (adjusted for carcass weight) are shown in Table 3.8. Average side length and femur weights were not significantly affected by sex of the animal. Steers had longer femur bones (411±2 vs. 400±2mm, P<0.005), greater fat depth (4.85±0.30 vs. 1.88±0.30mm, P<0.001) and heavier depots of kidney fat (5.23±0.20 vs. 2.40±0.20kg, P<0.001).

Treatment group F exhibited shorter average side length and femur length, greater fat depth and kidney fat weight than the RF and RS treatment groups. Femur weight of the RF treatment group was significantly heavier than the F and RS groups (2530±30 vs. 2330±30 and 2420±30g respectively).

Dressing out percentage was significantly higher (P<0.05) in the F treatment group than the RF and RS groups. No significant difference was found between bulls and steers. Heart weight was not significantly different between sex or treatment groups however, liver was significantly lighter (P<0.001) in the Treatment F group than the RF and RS groups, and in bulls than in steers (P<0.001).

Table 3.8. Least-squares means (±SE) for carcass characteristics and organ weights (adjusted for carcass weight) for the Fast (F), Restricted-Fast (RF) and Restricted-Slow (RS) treatment groups of bulls (B) and steers (S). Means within rows without common superscript letters were significantly different at $P<0.05$.

| | Group | | | | Sex | | |
|---|---|---|---|---|---|---|---|
| | F | RF | RS | P Value | B | S | P Value |
| DressingOut (%) | 53.3±0.6[b] | 50.9±0.6[a] | 51.0±0.6[a] | 0.05 | 51.9±0.5 | 51.6±0.5 | NS |
| Average Side length (mm) | 2029±11[a] | 2095±11[b] | 2089±11[b] | 0.001 | 2074±8 | 2069±8 | NS |
| Femur Length (mm) | 394±3[a] | 414±3[b] | 408±3[b] | 0.001 | 400±2 | 411±2 | 0.005 |
| Femur Weight (g) | 2330±30[a] | 2530±30[b] | 2420±30[a] | 0.001 | 2431±26 | 2421±26 | NS |
| Fat Depth (mm) | 5.10±0.37[b] | 2.56±0.36[a] | 2.45±0.36[a] | 0.001 | 1.88±0.30 | 4.85±0.30 | 0.001 |
| Kidney Fat (kg) | 5.88±0.25[b] | 2.49±0.25[a] | 3.08±0.25[a] | 0.001 | 2.40±0.20 | 5.23±0.20 | 0.001 |
| Heart (kg) | 1.89±0.04 | 1.94±0.04 | 1.94±0.04 | NS | 1.95±0.03 | 1.89±0.03 | NS |
| Liver (kg) | 5.85±0.12[a] | 6.73±0.12[b] | 7.01±0.12[b] | 0.001 | 6.25±0.09 | 6.81±010 | 0.001 |

### *3.3.5. Repeatability of Measurements*

Table 3.9 shows the correlation coefficients between the residuals of individual animals from the mean for their sex and treatment group for different average daily gains, measures of organic matter intake and gross feed efficiency. No consistent relationships appeared between average daily gains during the different periods. However, the liveweight gain to 18 months of age was highly significantly related to liveweight gain up to slaughter. Although several significant correlation coefficients between different organic matter intakes were found (d90-100 vs. d314-324 and d216-226 vs. d587-597), no consistent relationships were found between measurement periods.

Table 3.9. Correlation coefficients as measures of repeatability between residual measurements of the average daily gain, organic matter intake and gross feed efficiency at four occasions. Correlation coefficients are shown with levels of significance (*=P<0.05, **=P<0.01 and ***P<0.001).

Average daily gain

| Up to Day | d82 | d208 | d306 | D579 | 16mth |
|---|---|---|---|---|---|
| d82 | - | - | - | - | - |
| d208 | 0.41** | - | - | - | - |
| d306 | -0.02 | 0.07 | - | - | - |
| d579 | -0.31 | -0.03 | 0.32 | - | - |
| 16mth | 0.28* | 0.27* | 0.12 | 0.27 | - |
| Slaughter | 0.02 | 0.12 | 0.01 | 0.28 | 0.45*** |

Organic matter intake

| intake | d90-100 | d216-226 | d314-324 |
|---|---|---|---|
| d90-100 | - | - | - |
| d216-226 | 0.28 | - | - |
| d314-324 | 0.57*** | 0.17 | - |
| d587-597 | 0.36 | 0.52** | 0.10 |

Gross feed efficiency

| intake | d112 | d232 | d294 |
|---|---|---|---|
| d90-100 | - | - | - |
| d216-226 | 0.14 | - | - |
| d314-324 | 0.40* | 0.17 | - |
| d587-597 | -0.01 | 0.22 | -0.45 |

All the residuals for temperament indices had significant correlation coefficients with each other as shown in Table 3.10. This indicates that the measurements were repeatable and that animals which were calmer, remained calmer at each measurement. All residuals for weight-adjusted height measurements were significantly correlated with each other on days 83, 209 and 306. Height measures taken on d580 were not significantly related to the others, perhaps due to the lower numbers (n=40) measured on this day. Measures of residuals for cortisol, similarly, were significantly correlated on days 112, 232 and 294,

however those taken at slaughter were not significantly related with those taken from the live animal. Residuals for muscle glycogen levels did not show consistent relationships between individual measures.

Table 3.10. Correlation coefficients as measures of repeatability between residual measurements of temperament index, weight-adjusted height and cortisol levels at four occasions, and muscle glycogen levels at three occasions. Correlation coefficients are shown with levels of significance (*=P<0.05, **=P<0.01 and ***P<0.001).

| Temperament indices | | | |
|---|---|---|---|
| Day | d82 | d208 | d306 |
| d82 | - | - | - |
| d208 | 0.59 *** | - | - |
| d306 | 051 *** | 0.71 *** | - |
| d579 | 0.39 * | 0.63 *** | 0.59 *** |
| **Weight-adjusted height** | | | |
| Day | d83 | d209 | d307 |
| d83 | - | - | - |
| d209 | 0.48 *** | - | - |
| d307 | 0.48 *** | 0.36 ** | - |
| d580 | 0.30 | 0.22 | 0.29 |
| **Cortisol levels** | | | |
| Day | d112 | d232 | d294 |
| d112 | - | - | - |
| d232 | 0.29 * | - | - |
| d294 | 0.53 *** | 0.50 *** | - |
| slaughter | 0.25 | 0.12 | -0.07 |
| **Muscle glycogen** | | | |
| Day | d112 | d232 | |
| d112 | - | - | |
| d232 | 0.12 | - | |
| d294 | 0.33 * | 0.21 | |

### *3.3.6. Relationships with Growth*

Correlation coefficients between residuals of individual animals from the mean for their sex and treatment group for measurements of organic matter intakes,

gross feed efficiencies, temperament indices, weight-adjusted height, cortisol or glycogen levels; and the average daily gain for the period preceding measurement, average daily gain to 16 months and residuals for average daily gain to slaughter are shown in table 3.11. No significant relationships were found between the measurements and average daily gains, except weight-adjusted height on d209 and average daily gain to 16 months.

OMI was moderately correlated with longer-term liveweight gain (range 0.22-0.48) during the 1st, 2nd, and 4th intake periods (d90-100, d216-226 and d587-597, respectively). The relationship between OMI and LWG16 and LWGSLT was significant in the 2nd and 4th periods. Weight-adjusted height was significantly correlated with LWG16 during the d208/209 measurement, but was not significantly related at any other time (range –0.09 to 0.21). GFE, temperament index, cortisol and muscle glycogen were not significantly correlated with liveweight gains at any time.

Table 3.11. Correlation coefficients within each of the four intake measurement periods between measurements of organic matter intake, gross feed efficiency, temperament index, weight-adjusted height, plasma cortisol and muscle glycogen levels when compared with average daily gains during the period preceding measurement (LWG1-LWG4), up to approximately 16 months of age (LWG16), and up to slaughter (LWGSLT). Correlation coefficient is shown with levels of significance (*=P<0.05, **=P<0.01 and ***P<0.001).

| Day 82/83 measurements | | | |
|---|---|---|---|
| | LWG1 | LWG16 | LWGSLT |
| OMI | 0.23 | 0.30 | 0.29 |
| GFE | -0.03 | -0.14 | -0.21 |
| Wt.-adj. height | -0.09 | 0.15 | 0.05 |
| Temperament Index | 0.01 | -0.03 | -0.03 |
| Cortisol | -0.12 | 0.05 | 0.03 |
| Muscle Glycogen | -0.16 | 0.23 | 0.07 |
| **Day 208/209 measurements** | | | |
| | LWG2 | LWG16 | LWGSLT |
| OMI | 0.22 | 0.35* | 0.37* |
| GFE | 0.26 | -0.06 | 0.02 |
| Wt.-adj. height | 0.01 | 0.27* | 0.09 |
| Temperament Index | -0.07 | -0.05 | -0.10 |
| Cortisol | -0.05 | 0.11 | 0.03 |
| Muscle Glycogen | 0.19 | 0.16 | 0.06 |
| **Day 306/307 measurements** | | | |
| | LWG3 | LWG16 | LWGSLT |
| OMI | 0.13 | -0.01 | 0.01 |
| GFE | 0.25 | 0.08 | 0.10 |
| Wt.-adj. height | 0.09 | 0.06 | 0.01 |
| Temperament Index | 0.04 | -0.12 | -0.13 |
| Cortisol | 0.03 | -0.07 | -0.03 |
| Muscle Glycogen | -0.03 | 0.22 | 0.08 |
| **Day 579/580 measurements** | | | |
| | LWG4 | LWG16 | LWGSLT |
| OMI | 0.26 | 0.48** | 0.48** |
| GFE | 0.05 | 0.16 | 0.11 |
| Wt.-adj. height | 0.21 | -0.01 | -0.01 |
| Temperament Index | 0.25 | 0.20 | 0.20 |
| Cortisol at slaughter | -0.10 | -0.08 | -0.02 |

## 3.3. Discussion

The cattle involved in this experiment were concurrently involved in another trial investigating the effects of fast- versus slow-growing cattle on meat quality traits, especially meat tenderness. This provided the opportunity to examine relationships between growth and various other traits in cattle.

For unknown reasons, the cattle exhibited relatively slow growth (approximately 0.47 – 63.3kg LWG/d) from d0 to d100 although they were being fed *ad libitum*. The reason for this is unclear, however veterinary investigation at the time ruled out copper or selenium deficiency and suggested a benzimidazole drench resistance problem. The cattle were subsequently drenched throughout the remainder of the trial with Eprinex® pour-on (0.5% w/v eprinomectin, Merial New Zealand Ltd.) and growth improved markedly. Also of note is that although the RF and RS treatment groups were run as one mob of cattle from treatment allocation, the RF treatment group continued to outperform the RS treatment group in terms of liveweight gain. They required extra restriction on three occasions to keep these two groups at a similar weight due to the necessity to achieve similar weights at slaughter for the other concurrent experiment. Consequentially, no information is available as to the advantage in terms of ADG that the RF treatment group held, when grazing under restricted intake conditions.

The liveweight gains achieved by the F treatment group from d0 to d328 represent an 18% advantage to the bulls over steers under fast growth conditions. The bulls gained 9.8% faster than steers in the RF and RS treatment groups. Purchas and Grant (1995) demonstrated advantages of between 9.6-22.3% for bulls over steers in two different groups of Friesian x cattle grazing pasture over two years. Knight *et al.* (1999) found bulls gained 14% faster over

265 days. Lower differences have been observed under restricted feeding regimes (Price and Yeates 1971; Mickan *et al.* 1976).

Organic matter intakes (OMI) were measured on four occasions using the chromium intraruminal capsule technique. The OMI's measured on the four occasions appeared to be very low (Table 3.3). OMI values calculated on a per 100kg LWT basis of the F, RF and RS treatment groups ranged between 1.45-1.70, 1.19-1.53, 0.89-1.02 and 0.94-1.20kg OMI/100kg LWT/d for the four intake periods, respectively. Morris *et al.* (1993) estimated OMI's of 225kg Charolais cross steers at pasture achieving 0.54kg LWG/d to be 2.17kg OMI/100kg LWT/d at approximately 9 months of age (May). In comparison, the RS treatment group during the d90-100 intake period were approximately 247kg LWT growing at 0.54kg LWG/d and had an OMI of 1.70kg OMI/100kg LWT/d.

Similarly during the d216-226 intake period, the RS treatment group (330kg LWT and 1.60kg LWG/d) were estimated to be eating 1.53kg OMI/100kg LWT/d while Morris *et al.* (1993) conducting a second intake measurement at a similar time of year, found that 338kg steers gaining 1.68kg LWG/d had OM intakes of 2.39kg OMI/100kg LWT/d. Organic matter digestibility (OMD) of the herbage was 0.81 in their experiment, while ours was 0.80. Aranda-Orsorio *et al.* (1996) measured OMI's of 1.87kg OMI/100kg LWT/d for similar weight steers, growing at 0.71kg/d eating pasture with an OMD of 0.71.

Organic matter digestibility averaged approximately 0.75, 0.80, 0.59 and 0.78 for the d90-100, d216-226, d314-324 and d587-597 intake periods, respectively. The intakes calculated for the d314-324 intake period were probably influenced by the poor quality of the herbage offered (OMD approximately 0.59), however adjustment of the OMD values for this period did not fully restore the OMI's to acceptable levels. Estimated metabolizable energy (ME) requirements to support individual animals performance at each time were calculated using the formula of

SCA (1990), and related to the ME intakes calculated from the measured OMI's. This indicated that although the measured intakes were low, the relationships between the treatments and between bulls and steers were similar and therefore the values were reported as measured.

Several authors have indicated that reliable estimates of intake are difficult to obtain using the chromium capsule technique as generic *in vitro* digestibility measures must be applied to the individual (Parker *et al.* 1990; Realini 1998). Herd *et al.* (1996) suggested the limitation is largely due to variation in the rate of release of markers. The results of Archer *et al.* (1997) suggested that short measurement periods for feed intake would result in a loss of accuracy of data, even with perfect measures of feed intake, due to variability of intake over time.

During the d90-100 intake period when all cattle were under *ad libitum* feeding levels the F treatment animal's intake was significantly lower than that of the RF and RS treatment groups. This intake occurred prior to the end of the 100 day weight gain period used for allocation of treatments and all cattle were randomly assigned to two separate pastures, therefore this difference may be a random effect. During the d314-324 intake period, the RF and RS cattle were rotationally grazed onto pastures previously grazed by the F treatment cattle, which accounts for the significantly lower intake of the RS treatment cattle, although the difference between the F and RF cattle only approached significance ($P<0.10$).

Our values of Gross feed efficiency (GFE, Table 3.4) were high in comparison to the literature (Morris *et al.* 1993; Realini *et al.* 1999), reflecting the abnormally low intake measurements obtained. The relationships were, however, in agreement with the literature. During the d90-100 period under *ad libitum* feeding the bulls were significantly more efficient than the steers. This is supported by Galbraith and Topps (1981) who stated that bulls are more efficient by approximately 10%. During this period the F and RF treatment cattle were more efficient than the RS treatment group cattle which is supported by the

significantly higher growth rates achieved by these cattle under *ad libitum* feeding, when no significant differences in intake were observed. This suggests that feed efficiency is a determinant of differences between growth rate of cattle under *ad libitum* feeding at pasture.

During the subsequent intake periods when the RF and RS cattle were restricted in diet, the F treatment group had significantly greater GFE's than the two restricted groups. This is supported by Morris *et al.* (1993) and Realini *et al.* (1999) who found that GFE was significantly lower in cattle with restricted intakes and lower liveweight gains. No differences were observed between bulls and steers for any of these intakes, reflecting the effect of restriction on GFE.

Temperament scores were not significantly different between bulls and steers on any occasion (Table 3.5). This is supported by Voisinet *et al.* (1997a) who found that differences in temperament between sexes might not be evident when the scores are relatively low. No literature was found which examined the differences between bulls and steers specifically. The RF treatment group consistently exhibited lower temperament scores than both the F and RS groups, however the differences were only statistically significant on d208 and 579, probably due to the relatively high standard errors. This is difficult to interpret because the F treatment group exhibited high scores compared with the RF treatment group, and the literature suggests that heavier animals have calmer temperament (Fordyce and Goddard 1984; Fordyce *et al.* 1988). It would appear to suggest that the naturally faster-growing cattle (RF) had calmer temperaments than the naturally slower-growing cattle (RS) when run together as supported by the literature (Tulloh 1961; Fordyce and Goddard 1984; Burrow and Dillon 1997; Voisinet *et al.* 1997a; Immonen *et al.* 2000). The elevated temperament scores of the F treatment group on d83 when all the cattle were run together is, however, contradictory to this.

Plasma cortisol levels were in agreement with levels of 13-63ng/ml reported by Grandin (1997) when animals were restrained in a headbail. Cortisol levels were significantly lower in bulls than in steers on all occasions suggesting that steers may have been under chronic stress and that the stress was not adapted to throughout the trial. Others have found lower cortisol levels in steers than in bulls (Doornebal 1977). No differences in muscle glycogen were evident between bulls and steers throughout the study. The fact that both cortisol and muscle glycogen levels of F treatment group on d294 were elevated, suggests that there may have been differences in handling between the two groups prior to sampling. Differences between treatments in cortisol levels at slaughter are confounded by different slaughter dates and times so no conclusions can be drawn from these, however the difference between bulls and steers can be examined as equal number of bulls and steers were slaughtered on each occasion. The elevated levels of both bulls and steers suggests that acute stress was applied prior to slaughter, possibly due to factors such as trucking and the cattle being subjected to a different environment.

Weight-adjusted heights of the cattle appeared to increase in difference between bulls and steers as the trial progressed, with no difference at d83, and bulls being significantly shorter at the same weight by 19, 24 on 33mm on d209, d307 and d580, respectively. This indicates that bulls were heavier than steers at a given height, which would be expected given the faster growth rates achieved. Shorter femur bones at the same weight indicate that the bones of bulls were denser or thicker. Lower fat depths and kidney fat weights are indicative of bull's propensity toward muscle deposition over fat deposition (Baker *et al.* 1992; Purchas and Grant 1995). No significant differences were found in weight-adjusted height between treatment groups at anytime, indicating no differences in potential mature weight. This is to be expected, as these animals are all of one breed. Treatment group F exhibited shorter average side length and femur length, greater fat depth and kidney fat weight than the RF and RS treatment groups. This is attributable to the faster growth to achieve earlier slaughter of the

treatment F cattle (16-18 months vs. 25 months of age), resulting in shorter, more compact carcasses (Purchas and Grant 1995). The lack of difference in weight-adjusted heights between treatment groups is not contradictory to the differences in average side length and femur length at slaughter due to different slaughter ages between treatment groups. Treatment RF cattle had significantly heavier femur bones than the RS cattle, but no difference in length. This is suggestive that the naturally faster growing cattle have denser or thicker bones than naturally slower growing cattle slaughtered at the same time and grown at the same rate, although dressing out percentage was not significantly different at 51.0% for the RF and RS cattle.

Breed or treatment did not significantly affect weight of heart at slaughter. Liver weight was lower in the F treatment group than in the RS and RF groups, possibly reflecting the differences in age at slaughter. No difference was observed between the liver weight of the RS and RF treatment group cattle indicating that on restricted feeding, metabolic rate of naturally faster and slower growing cattle were not different. Bulls had significantly lighter livers than steers suggesting that the maintenance requirement of bulls may be lower than steers (Ferrell and Jenkins 1985; Johnson *et al.* 1990; Early *et al.* 1990).

Repeatability of measures of traits over time revealed no consistent relationships between sequential measures of average daily gain, intake or GFE. This indicates that these traits were not repeatble between animals over time. Intakes are affected by numerous animal and pasture factors which would explain the variation in intakes (Scott *et al.* 1976; Geenty and Rattray 1987) along with difficulties of obtaining accurate individual intake estimates as pointed out above. Feed conversion efficiency is affected by factors such as composition of growth and maintenance requirement (Renand *et al.* 1992) as well as accuracy of intake estimates, which would explain the lack of repeatability for this trait. The lack of consistent repeatability between measures of ADG is indicative of the variations

in seasonal management that is normal under year-round pastoral systems (Nicol and Nicoll 1987).

Temperament scores exhibited significant correlations between times of measurement on all occasions (0.39-0.71), which indicates that the measures used were good measures of the animals temperament and that the individuals temperament was consistent over time. That is to say, calmer animals are consistently calmer which is supported by the results of others (Hearnshaw and Morris 1984; Fordyce and Goddard 1984; Grandin 1993). Plasma cortisol levels were repeatable between different times with correlations of 0.29-0.48. This suggests that cortisol is a good indicator of chronic stress in beef cattle. No consistent relationships between sequential measures of muscle glycogen were found suggesting that muscle glycogen is less useful in indicating chronic stress than in indicating physical activity.

Weight-adjusted heights were highly repeatable when all 60 cattle were measured (0.36-48), however measures on d580 when only 40 cattle were measured, were not significantly correlated with the earlier measurements (0.22-0.30).

To determine relationships between the individual traits measured and liveweight gain, we calculated correlation coefficients between the residuals for individual trait and liveweight gains for the period preceding the measurement, liveweight gain up to 16 months of age (when all animals were present) and liveweight gain up to the slaughter. Correlations were low or close to zero and were generally not statistically significant.

Correlations between OMI and liveweight gains for the d216-226 (0.35 and 0.37) and d587-597 (0.48 and 0.48) intake periods were significantly related to LWG16 and LWGSLT. The remainder of relationships for the d90-100, d216-226 and d587-597 intake periods were moderate (0.22-0.30) but not significant. OMI's in the d314-324 period showed low relationships with growth rate (-0.01 to 0.13)

possibly due to poor feed quality and subsequent liveweight loss of some animals during this time.

Temperament score had generally low (not significant) correlations with long-term growth. With the high level of repeatability of temperament scores indicating that calmer animals were consistently calmer, this suggests that temperament is not related to growth rate in cattle. This is contradictory to a number of other studies where relationships for temperament and liveweight gain of between -0.16 to -0.58 have been found (Fordyce and Goddard 1984; Wulf *et al.* 1997; Voisinet *et al.* 1997a; Immonen *et al.* 2000). However, many of these studies were completed under feedlot or sub-tropical grazing conditions where competition for feed may play a greater role than under extensive New Zealand pastoral systems. Blockey and Lade (1974) found that relationships between dominance and liveweight gain were apparent under restricted feeding but not when pasture supply was abundant.

Cortisol and muscle glycogen showed no significant relationships with long-term growth. Purchas *et al.* (1980) proposed that higher plasma cortisol levels could be related to slower growth rates, but evidence for this is equivocal. No prior studies were found that has examined the relationship between muscle glycogen levels and liveweight gain. As cortisol was significantly lower in bulls than in steers on all occasions, and the bulls grew faster than steers throughout the trial, no relationship between cortisol and liveweight gain could suggest that chronic stress does not influence liveweight gain.

A relationship between weight-adjusted height and liveweight gain would be expected based on the literature (Section 2.2.1). Frame size measurements have been shown to be a good indicators of mature weight (Owens *et al.* 1993) and numerous studies have shown strong relationships between potential mature weight and liveweight gain of cattle of between 0.32-0.92 (Lickley *et al.* 1960; Brown *et al.* 1972b; Owens *et al.* 1993). In this study, withers height as a measure

of potential mature weight had variable, but low, correlation with long-term liveweight gain (-0.01 to 0.27) and was only significantly related on one occasion to liveweight to 16months of age.

In conclusion, these results suggest that no consistently significant relationships existed for this group of cattle between long-term growth rates and the individual measures of feed conversion efficiency, mature weight, temperament and stress taken at points throughout the life of the cattle. Moderate but inconsistent relationships between OMI and longer-term gain were evident. This is in contrast to the literature where relationships have been found for each of these traits and liveweight gain. In the case of intake, and consequently GFE, inaccuracies of measurement appear to have influenced results, however the repeatabilities observed for the measurement of the other traits suggest that methodology was not the cause for the poor relationships with liveweight gains that were observed. Few studies have related these traits to liveweight gain over such a long time period at pasture, as in this trial. This, and the lack of repeatability between different periods of liveweight gain, suggests that variability of liveweight gain over time negated any short-term relationships.

## APPENDIX 1. TIMETABLE OF EVENTS

| DATE | DAY NO. | TASK |
|---|---|---|
| 26 Mar 1997 | 0 | Weigh Full |
| 27 Mar | 1 | Weigh Fasted |
| 16 Apr | 21 | Weigh Full |
| 8 May | 43 | Weigh Full |
| 11 Jun | 77 | Weigh Full |
| 16 Jun | 82 | Weigh Full, Temperament measurement |
| 17 Jun | 83 | Weigh Fasted, wither height, Insert CRC |
| 24 -28 Jun | | Faecal Sample 1 |
| 30 -04 Jul | | Faecal Sample 2 |
| 04 Jul | 100 | Weigh Full |
| 05 Jul | 101 | Weigh Fasted |
| 16 Jul | 112 | Muscle biopsy, Sort treatment groups |
| | | Begin Restriction of RF and RS groups |
| 13 Aug | 140 | Weigh Full |
| 10 Sep | 168 | Weigh Full |
| 20 Oct | 208 | Weigh Full, Temperament measurement |
| 21 Oct | 209 | Weigh Fasted, Withers Height , Insert CRC, Drenched |
| 28 Oct - | | Faecal Sample 3 |
| 01 Nov | | |
| 03 -07 Nov | | Faecal Sample 4 |
| 07 Nov | 226 | Weigh Full |
| 08 Nov | 227 | Weigh Fasted |
| 13 Nov | 232 | Muscle biopsy |
| 16 Dec | 265 | Weigh Full |
| 14 Jan 1998 | 294 | Weigh Full, Muscle biopsy |
| 26 Jan | 306 | Weigh Full, Temperament measurement |
| 27 Jan | 307 | Weigh Fasted, Withers Height , Insert CRC |

| | | |
|---|---|---|
| 03-07 Feb | | Faecal Sample 5 |
| 09 -13 Feb | | Faecal Sample 6 |
| 13 Feb | 324 | Weigh Full |
| 14 Feb | 325 | Weigh Fasted |
| 17 Feb | 328 | F Bulls slaughtered |
| 11 Mar | 350 | Weigh Full |
| 23 Mar | 362 | Weigh Full |
| 21 Apr | 391 | Weigh Full |
| 20 May | 420 | Weigh Full |
| 6 Jul | 467 | Weigh Full |
| 13 Aug | 505 | Weigh Full |
| 11 Sep | 534 | Weigh Full |
| 13 Oct | 566 | Weigh Full |
| 26 Oct | 579 | Weigh Full, Temperament measurement |
| 27 Oct | 580 | Weigh Fasted , Withers Height, Insert CRC |
| 03 -07 Nov | | Faecal Sample 7 |
| 09 -13 Nov | | Faecal Sample 8 |
| 13 Nov | 597 | Weigh Full |
| 14 Nov | 598 | Weigh Fasted |
| 16 Nov | 600 | Slaughter RF and RS bulls |
| 23 Nov | 607 | Slaughter RF and RS steers |

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