# PERFORMANCE OF HEREFORD AND HOLSTEIN HEIFERS ON KIKUYU PASTURE (*Pennisetum clandestinum*), USING N-ALKANES FOR DETERMINATION OF DIGESTIBILITY AND DRY MATTER INTAKE

by

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# DECLARATION

I hereby declare that the results contained in this thesis are from my own original work and do not include work which has been previously published, except where due reference is made in the text.

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## ABBREVIATIONS

'A' - asymptotic mature mass

ADF - acid detergent fibre

ADG - average daily gain

ARC - Agricultural Research Council

'b' - Huxley's (1932) allometric coefficient

CF - crude fibre

CP - crude protein

CV - coefficient of variation

Dj - amount of synthetic alkane dosed daily to the animals

DDM - digestible dry matter

DM - dry matter

DMD - dry matter digestibility

DMI - dry matter intake

DOM - digestible organic matter

EE - ether extract

Fi - concentration of the odd-chain length alkane in the faeces

Fj - concentration of the even-chain length alkane in the faeces

Hereford (C) - Hereford treatment receiving concentrate

Hereford (WC) - Hereford treatment not receiving concentrate

Hi - concentration of the odd-chain length alkane in the herbage

Hj - concentration of the even-chain length alkane in the herbage

HPC - high protein concentrate

I - intake of grazed herbage

L.W - liveweight

ME - metabolizable energy

MFW - mobile feed wagon

NFE - nitrogen-free extract

NPN - non-protein nitrogen

O - faecal output

'P' - stage of maturity

'q' - Butterfield's (1983) growth coefficient

R - rate of consumption of grazed herbage

T - time spent grazing

'W' - current weight of animal

# ABSTRACT

Kikuyu pasture (*Pennisetum clandestinum*) is potentially the most important source of roughage used to feed dairy heifers in summer in KwaZulu-Natal. It is commonly believed that on kikuyu pasture beef breed females grow at a faster rate than those from dairy breeds when no supplementation is given. Little conclusive evidence is, however, available to support this. Explanations as to why such differences may exist are also limited.

Eight Hereford and eight Holstein heifers of similar age and maturity stage were used in a trial. The trial was run over a twenty week period. For the first ten weeks all the animals in the trial grazed *ad libitum* kikuyu pasture with no supplementation except for a mineral lick. Over this (grass only) period the two breed groups formed the two treatments. During the second ten week period of the trial all of the Holsteins and four of the Herefords were fed a restricted but equivalent amount (1.7 kg) of a maize meal based concentrate. The use of a computerized, mobile feeding system allowed concentrate intake of individual animals to be measured. Animal height, weight and condition score readings were taken weekly over the grass only and the concentrate (final seven weeks) periods of the trial. Herbage intake and digestibility were estimated using n-alkanes as indigestible markers in two experiments conducted during the grass only and concentrate periods.

The Herefords had a significantly higher ADG than the Holsteins (0.82 vs. 0.04 kg/day; $P < 0.01$) over the grass only period. During the concentrate period the rate of mass gain of the Holstein treatment did not differ significantly ($P > 0.05$) from the Hereford treatment receiving concentrate. The Herefords receiving concentrate were also not significantly different ($P > 0.05$) in rate of mass gain from the Herefords not receiving concentrate. Rate of height gain was not significantly different ($P > 0.05$) between treatments over either the concentrate or the grass only periods. During the grass only period the Holsteins lost condition (0.07 condition score units per week) whilst the Herefords gained condition at an equivalent rate.

The voluntary intake of concentrates was not significantly different ($P > 0.05$) between the Herefords and Holsteins (19.19 vs. 16.40 g/kg/L.W(liveweight)$^{0.75}$). Regression coefficients relating level of concentrate intake to rate of mass gain were also not significant ($P > 0.05$) for either of the treatments receiving concentrate.

The use of n-alkanes as indigestible markers showed the intake of the Holstein treatment to have an intake 55% ($P < 0.01$) higher than the Herefords (185.4 vs. 120.5 g/kg $L.W^{0.75}$) over the first experiment where both treatments were grazing *ad lib.* kikuyu alone (grass only period). During the concentrate period intake of the Herefords receiving concentrate exceeded that of the Holsteins ($P < 0.01$) by 23% (139.1 vs. 113.2 g/kg $L.W^{0.75}$). Review of the literature, suggests that the double alkanes technique greatly over-estimated intake. Errors in herbage sampling (accentuated by pasture rotation in the first experiment), a low daily dose of the synthetic alkane ($C_{32}$) and incorrect estimation of the $C_{32}$ content in the daily doses are identified as possible causes of the over-estimation of intake.

Faecal recoveries of the herbage n-alkanes were demonstrated to increase with increasing chain length and hence $C_{35}$ was proposed as the most reliable herbage alkane for dry matter digestibility determination. Digestibility differences between treatments estimated using the $C_{35}$ alkane were not significantly different ($P > 0.05$) in either the first or second experiments. The mean digestibility estimates (using the $C_{35}$ alkane) for the first and second experiments were 64.9 and 56.61%, respectively.

In conclusion, higher growth rates of Herefords on kikuyu pasture would seem to be primarily due to differences in the dry matter intake of the grazed herbage. Further work using other breeds of dairy and beef animals is required. The underlying cause of differences in dry matter intake between breeds also requires investigation.

## CONTENTS

**CHAPTER 1**

## CHAPTER 2

# CHAPTER 1

# REVIEW OF LITERATURE

## 1.1 The Use of n-alkanes to Estimate Herbage Intake and Dry Matter Digestibility of Kikuyu (*Pennisetum clandestinum*)

### 1.1.1 Introduction

The performance of ruminants on pasture reflects a balance between the animal's nutrient demands on the one hand, and the supply of nutrients obtained from the forage on the other. Whilst there is considerable knowledge available on both the nutrient requirements of the animal as well as the quality of the forage on offer, far less is known about the actual amount of forage consumed by the animal, and its utilization within the animal. "When forage is the sole source of nutrients, production is invariably much lower than the genetic potential of the animal" (Minson, 1990), thus emphasising the importance of optimizing supply and demand interactions when ruminants are on pasture. An ability to accurately estimate herbage intake, as well as dry matter digestibility, would clearly help in the achievement of this goal.

### 1.1.2 Techniques for measurement of herbage intake and digestibility

Several techniques have been previously described for the estimation of forage intake on pasture. These vary from the use of short term changes in liveweight to studies in grazing behaviour and the use of the difference between the weight of forage dry matter (DM) before and after grazing (Minson, 1990). The single stem disc meter may be used to estimate the weight of forage on offer. This instrument is simple to use, easy to construct, inexpensive, durable, and easy to handle. It can therefore be operated by relatively unskilled labour and in addition, measurements can be taken with minimal disturbance to pasture (Bransby and Tainton, 1977). Bransby and Tainton

(1977) reported that realistic estimates were obtained using the disc meter to estimate average daily intake of a 150 cow Friesian herd in short rotation.

Garrigus (1934) was the first worker to suggest that the dry matter intake (DMI) of forage could be estimated through the use of faecal output (O), and dry matter digestibility (DMD) using the following equation :

$$DMI = \frac{O}{1 - DMD} \tag{1}$$

The apparent digestibility coefficients for the forage in question would have been obtained from feeding fresh cut forage to animals in stalls, whilst total faecal output was obtained from the weight of faeces collected in canvas faecal collection bags attached to the animal. Several problems suggest that total faecal collection in the field may be impractical (Corbett, 1978). These include :

(i) a disturbance of the animal's performance and behaviour;
(ii) difficulty in separating urine from the faeces in females; and
(iii) biased estimates owing to incomplete collection.

The need for total faecal collection is avoided by the use of indigestible markers, where faecal output can be estimated using the following equation :

$$O\ (DM) = \frac{Mass\ of\ tracer\ fed}{Mass\ of\ tracer\ per\ unit\ of\ dry\ faeces} \tag{2}$$

(after Raymond and Minson, 1957).

A major disadvantage of this approach is that a single digestibility value is ultimately applied to all animals in a group, despite the fact that both the level of intake of individual animals and the consumption of supplement can alter herbage digestibility (Dove *et al.*, 1989a). Although the use of many markers has been researched, it would seem that chromic oxide has been by far the most widely used. A major problem with the use of external markers such as chromic oxide is their uneven excretion in the faeces (Minson, 1990). Langlands *et al.* (1963) found two sources of error when determining the faecal outputs of cattle and sheep using chromic oxide as a marker :

(i) a discrepancy between grab and representative samples in the concentration of chromic oxide; and

(ii) the failure of marker output to equal marker intake during the period of estimation.

Although such errors could result from experimental error, Raymond and Minson (1957) have argued that the chromic oxide technique tends to estimate the quantity of faeces containing the amount of marker dosed in 24 hours, and that the quantity of faeces excreted during a period of a few days may not correspond to marker dose if there are short-term changes in the rate of passage and period of retention of digesta. Raymond and Minson (1957) concluded that the use of chromic oxide as a marker, together with the faecal index technique for estimating herbage digestibility, would enable general trends of daily herbage intake to be studied under different management systems. However the greatest problem here would be to obtain a representative faecal sample due to diurnal variations in faecal chromic oxide levels.

Grace and Body (1981) were the first workers to suggest the use of components of plant cuticular wax as markers for determining herbage intake and digestibility in ruminants. They found that in the case of the $C_{19}$ to $C_{32}$ fatty acids, the faecal outputs of these fatty acids by the animal were not significantly different from the amounts ingested, showing that they were apparently not absorbed in the digestive tract. Further, they proposed that it would not be necessary to determine the digestibility of the herbage grazed, as the intakes are calculated from the daily faecal outputs of the $C_{19}$ to $C_{32}$ fatty acids and their concentration in the herbage. However, they did find that, as with previous methods for measuring digestibility, the problem of sampling herbage which represents that eaten by the animal still exists.

Long-chain fatty acids are, in fact, only a minor component of unsaponified plant cuticular wax with a typical level of less than 10% in the Poaceae (Tulloch, 1976). Alkanes, having typical levels of between 3 and 40% in the plant cuticular wax (Tulloch, 1976), were first studied as having a possible role as markers by Mayes *et al.* (1986a). The advantage of alkanes as markers over long-chain fatty acids is ease of analysis. Mayes *et al.* (1986a), however, suggested that the faecal recovery of alkanes was incomplete. He overcame this problem by arguing that incomplete faecal recovery would not be of significant consequence if the animals were dosed with synthetic, even-chained alkanes as external markers for the estimation of faecal output, provided that the pair of natural (odd-chain) and synthetic (even-chain) alkanes had similar faecal recoveries. If this assumption is met, errors cancel out in the numerator and denominator (equation (1)). This technique is superior to the widely used chromic oxide technique because it does not require an independent assessment of digestibility and does not rely on the quantitative recovery of the dosed n-alkane as the marker (Vulich *et al.*, 1991).

### 1.1.3 Using alkanes to measure herbage intake and digestibility

If a synthetic even-chain length alkane is dosed together with a chosen naturally occurring odd-chain length alkane, then an equation to calculate intake can be derived as follows (Dove and Mayes, 1991) :

Let the concentrations of the natural odd-chain alkane in herbage and faeces be Hi and Fi respectively, and the concentrations of the synthetic (dosed) alkane in herbage and faeces be Hj and Fj respectively. Then the indigestibility of the herbage is given by:

$$Indigestibility = \frac{Hi}{Fi} \qquad (3)$$

and faecal output is given by:

$$O = \frac{Dj + I * Hj}{Fj} \qquad (4)$$

where Dj is the amount of synthetic alkane dosed to the animal.

Then using equation (1), intake dry matter intake can be calculated as :

$$DMI = \frac{Dj + I * Hj}{Fj} / \frac{Hi}{Fi} \qquad (5)$$

This can be rearranged as :

$$DMI = \frac{\frac{Fi}{Fj} * Dj}{Hi - \frac{Fi}{Fj} * Hj} \qquad (6)$$

*1.1.3.1 Faecal recovery of alkanes and obtaining a representative sample*

It would seem apparent that the faecal recovery of n-alkanes of both odd- and even-chain length in the faeces increases with increasing carbon chain length (Dove *et al.*, 1989b; Mayes and Lamb, 1984; Mayes *et al.*, 1986a; Mayes *et al.*, 1986b; Dillon and Stakelum, 1988). Casson *et al.* (1990) found a quadratic correlation ($r^2$=0.985) between chain length and faecal recovery with sheep grazing Medicago cultivars. Vulich *et al.* (1991), however, found no significant effect of n-alkane chain length on faecal recovery rate for either the odd- or even-chain length alkanes. Observed trends in faecal recovery values for alkanes of different chain lengths are shown in Table 1.1. Despite observed trends in the recovery pattern between individual alkanes there may be differences in the absolute faecal recovery values of specific alkanes between trials (Dove *et al.*, 1989b), thus implying that it would not be valid to use the faecal levels of the natural alkanes to obtain an absolute estimate of herbage digestibility, or alternatively the dosed alkane to obtain an absolute estimate of faecal output.

**Table 1.1.** Faecal recoveries of n-alkanes

| | n-alkanes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Researcher | $C_{28}$ | $C_{29}$ | $C_{30}$ | $C_{31}$ | $C_{32}$ | $C_{33}$ | $C_{35}$ | $C_{36}$ |
| Vulich *et al.* (1991) | 0.93 | 0.91 | 0.96 | 0.93 | 0.88 | 0.88 | 0.91 | 0.86 |
| Mayes *et al.* (1986b) | | 0.61 | | 0.74 | 0.82 | 0.82 | 0.93 | |
| Mayes *et al.* (1984) | | 0.72 | | 0.83 | | 0.91 | 0.98 | |
| Dove *et al.* (1989a)[1] | 0.7 | 0.77 | 0.76 | 0.88 | 0.84 | 0.87 | | |
| Dove *et al.* (1989b)[1] | 0.85 | 0.91 | 0.88 | 0.93 | 0.95 | 0.89 | | 0.95 |
| Mayes *et al.*[2] (1986c) | | | | 0.59 | 0.77 | 0.807 | | 0.93 |

[1] cattle used (otherwise sheep)

[2] Dove *et al.* (1989a) dosed sheep with $C_{32}$, whereas Dove *et al.* (1989b) dosed sheep with $C_{28}$, $C_{32}$, and $C_{36}$.

It is clear that, in order for accurate estimates of intake to be achieved using equation (6) faecal recoveries of the dosed and naturally occurring alkane must be equal. Non-equivalent faecal recoveries lead to either over- or under-estimations of herbage intake. If the faecal recovery of alkanes does indeed increase with increasing carbon chain length, and odd- and even-chain length alkanes behaved in a similar manner in the digestive tract, then one might expect the faecal recovery of even chain alkanes to be intermediate between the recovery values of adjacent odd-chain alkanes. Mayes *et al.* (1986a), however found the recovery of dosed $C_{28}$ to be higher than the recoveries of both $C_{27}$ and $C_{29}$, and the recovery of dosed $C_{32}$ to be similar to the recovery of $C_{33}$. Dove and Mayes (1991) claimed that, as alkane chain length increases, the difference in recovery between adjacent alkanes decreases. Although the faecal recoveries of $C_{35}$ and $C_{36}$ may be higher and of greater similarity than the $C_{32}$-$C_{33}$ alkane pair, few pasture species have levels of $C_{35}$ over 50 mg/kg. Laredo *et al.* (1991) defined this as the minimum level required for intake estimation. The best estimates of herbage intake may, thus, be obtained from the $C_{32}$-$C_{33}$ alkane pair. This has been shown to be true in practice for sheep (Mayes *et al.*, 1986a), whilst Vulich *et al.* (1991) found that the $C_{31}$-$C_{32}$ alkane pair estimated intake with similar precision to the $C_{32}$-$C_{33}$ alkane pair in sheep. In cattle, the $C_{32}$-$C_{33}$ pair of alkanes was shown to accurately estimate intake (Mayes *et al.*, 1986c). However, Dove and Mayes (1991) suggest that, in cattle, more work is required to obtain further estimates of alkane recovery, which tends to be more variable in cattle than sheep.

The explanation for incomplete alkane recovery seems to be related to post-ruminal losses in both the small and large intestine, whilst losses of alkanes in the forestomachs appears to be relatively small . This was shown using cannulated sheep, allowing analysis of the alkane fraction of the digesta at the duodenum, terminal ileum, and in the faeces (Mayes *et al.*, 1988; Kafilzadeh and Parker, 1990). Although alkanes are found in ruminant tissues (Muccio *et al.*, 1984), these tissue alkanes occur in trace concentrations which are too low to explain the fate of absorbed alkanes from the intestines. In fact, the fate of absorbed alkanes in the ruminant appears to be unknown. It would appear, however, that these alkanes are of dietary origin, as the rumen microflora have a negligible ability to synthesise alkanes (Mayes *et al.*, 1988). The predominance of odd-chain tissue alkanes observed by Muccio *et al.* (1984) may go some way to explaining the higher faecal recovery of even-chained alkanes relative to adjacent odd-chain alkanes. Secretion of alkanes into the gut is clearly likely to be a relatively small source of error in the determination of herbage intake using alkanes.

There is disagreement amongst researchers regarding the extent of diurnal variation in faecal alkane levels. This is obviously of considerable importance in determining the frequency of faecal sampling required. Reduced faecal sampling constitutes a considerable labour saving, especially in trials where large numbers of animals are used. Dillon and Stakelum (1989) found significant diurnal variation in faecal alkane levels in dairy cows with both once- and twice-daily dosing. When looking at the ratios of pairs of natural and dosed alkanes, Dillon and Stakelum (1989) found that the variation was greater with once-daily compared to twice-daily dosing. As the level of odd-chain alkanes tended to be relatively constant throughout the day, it was concluded that the dosed, even-chain alkanes were responsible for most of the diurnal variation. Ratios rather than the levels of individual faecal alkanes are examined, as these are more relevant to the calculation of intake. Mayes *et al.* (1986a) however, found no evidence of systematic variation throughout the day (when examining faecal alkane ratios in twelve sheep based on sampling at three hourly intervals over a 24 hour period) (Figure 1.1). None of the plotted points differed significantly from unity. Mayes *et al.* (1986b) concluded that diurnal variation in faecal excretion is small, and that dosing and faecal sampling once each day should be adequate.

In a later trial, Stakelum and Dillon (1990) (cited by Dove and Mayes, 1991) found lower levels of diurnal variation in faecal alkane levels in cattle than previously mentioned. Faecal alkane ratios showed variation amounting to c 5% of mean marker concentrations. It would, thus, seem that the effect of diurnal variation in faecal alkane levels may be relatively small, and once daily faecal collection may suffice. However in cattle the extent of diurnal variation is difficult to ascertain due to the small body of published literature in this regard. Available evidence suggests that this variation may exist because odd-chained alkanes tend to associate with the particulate phase of the digesta whilst even-chained alkanes tend to associate with the liquid phase of the digesta (Mayes *et al.*, 1988).

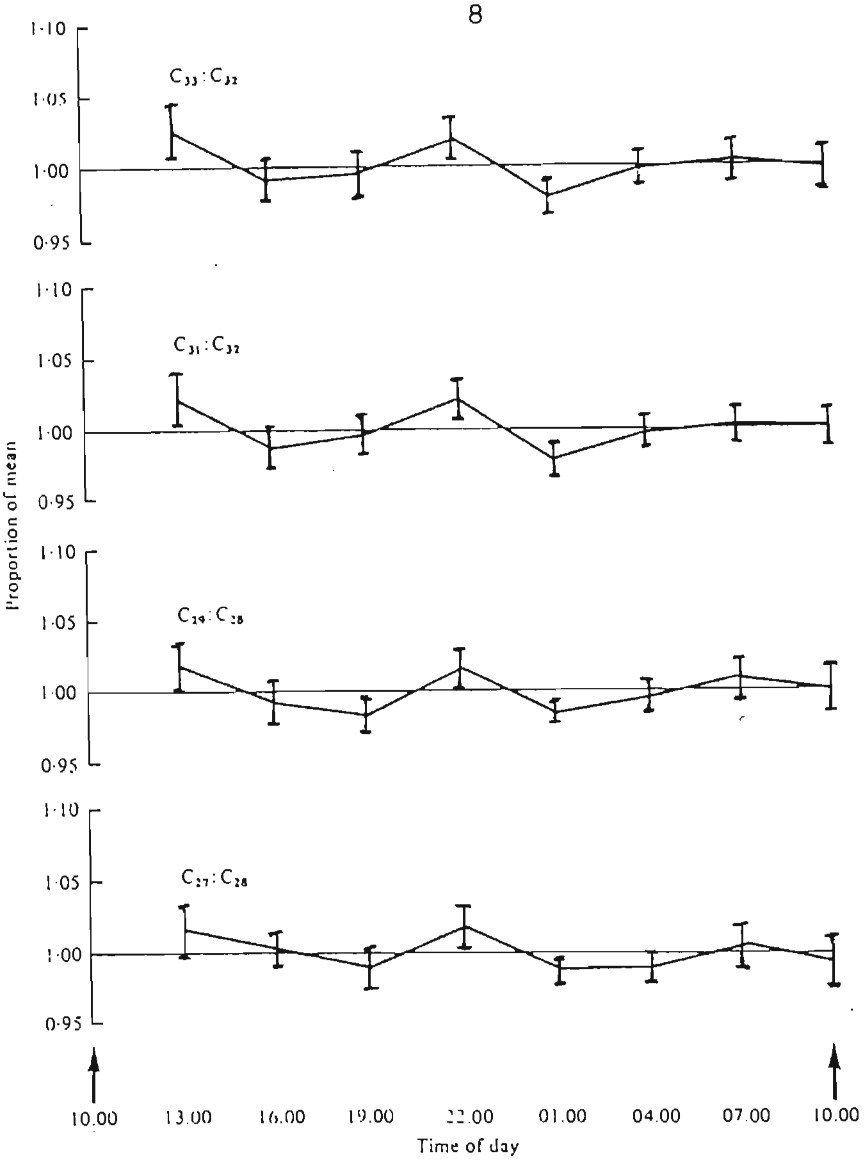

**Figure 1.1.** Mean variations throughout the day in ratios in faeces of odd-chain (herbage) n-alkane concentrations to even-chain (dosed) n-alkane concentrations expressed as proportions of the mean value for each lamb. Animals were dosed at 10:00. (after Mayes *et al.* 1986a).

### *1.1.3.2 Herbage sampling*

One of the greatest problems in using the double alkanes technique to estimate herbage intake in a grazing situation is the difficulty in obtaining a representative sample of the herbage. As the proportionate bias in the estimation of intake arising from unit proportionate error in herbage $C_{33}$ has been demonstrated to range between ± 1.1 times the error in $C_{33}$ compared with a factor of less than 0.1 for error in the herbage $C_{32}$(Vulich *et al*, 1993), it would seem clear that the herbage odd-chain length alkane is the important consideration for in accurate herbage sampling. The alkane profile of the herbage consumed by the animal varies at three levels :

(i) different plant species differ greatly in their concentrations of alkanes (Laredo *et al.*, 1991);

(ii) physiological growth stage, vegetative cycle, and environmental conditions may significantly influence the concentrations of certain alkanes within certain plant species (Laredo *et al.*, 1991; Malossini *et al.*, 1990); and

(iii) there is a high level of variation in the alkane profiles between different components of a specific plant (Laredo *et al.*, 1991).

The effect of different plant species with different alkane profiles is not a concern where animals are grazing a monospecific pasture. Although plants differ greatly in their alkane profiles, most have considerably higher levels of the odd-chain than even-chain alkanes, and, of these, $C_{29}$, $C_{31}$, and $C_{33}$ appear to be the most common (Dove and Mayes, 1991; Malossini *et al.*, 1990; Laredo *et al.*, 1991). It should be remembered that a minimal concentration of 50 mg/kg of the chosen natural alkane is required in the herbage (Laredo *et al.*, 1991). Laredo *et al.* (1991), after assessing the suitability of tropical species for the double alkanes technique, concluded that some species contain insufficient $C_{33}$ alkane. Hence, shorter chain length alkanes will have to be used indigestible markers, leading to a reduction in the accuracy of estimating intake.

Malossini *et al.* (1990) found that three out of six pasture species studied showed significant differences in total n-alkane content between the first and second vegetative cycles ($P < 0.05$). The total n-alkane content of *Lolium multiflorium* increased, whilst that of *Medicago sativa* and *Trifolium pretense* decreased. Differences in individual n-alkanes were only randomly distributed without any particular patterns. Malossini *et al.* (1990) commented that the lack of systematic differences in the n-alkane content between the two vegetative cycles was perhaps due to the fact that the stage of development in the second growing cycle was different depending on the plant species considered, even if they were of approximately the same age. It was concluded that, of the biological factors involved, the growth stage of the plant probably plays a more important role than the vegetative cycle. Environmental factors have also been shown to have an influence on the total alkane content of many plants, with most plants having higher levels of n-alkanes in summer than winter (Laredo *et al.*, 1991). This may be explained by the suggestion of Baker (1980) that an increase in radiant energy flux and decreases in humidity and soil moisture can have stimulatory effects on wax production.

When measuring intake using the double alkanes technique on a monospecific pasture, variation in the concentrations of specific alkanes between various components of the plant can cause a large source of error in obtained estimates of intake. Stems usually have lower concentrations of alkanes than leaves (Figure 1.2), and older leaves tend to have a lower concentration of alkanes than younger leaves (Laredo *et al*, 1991). A possible explanation for declining alkane content as leaves mature is that specific leaf weight tends to be higher with older leaves (Wilson, 1976).

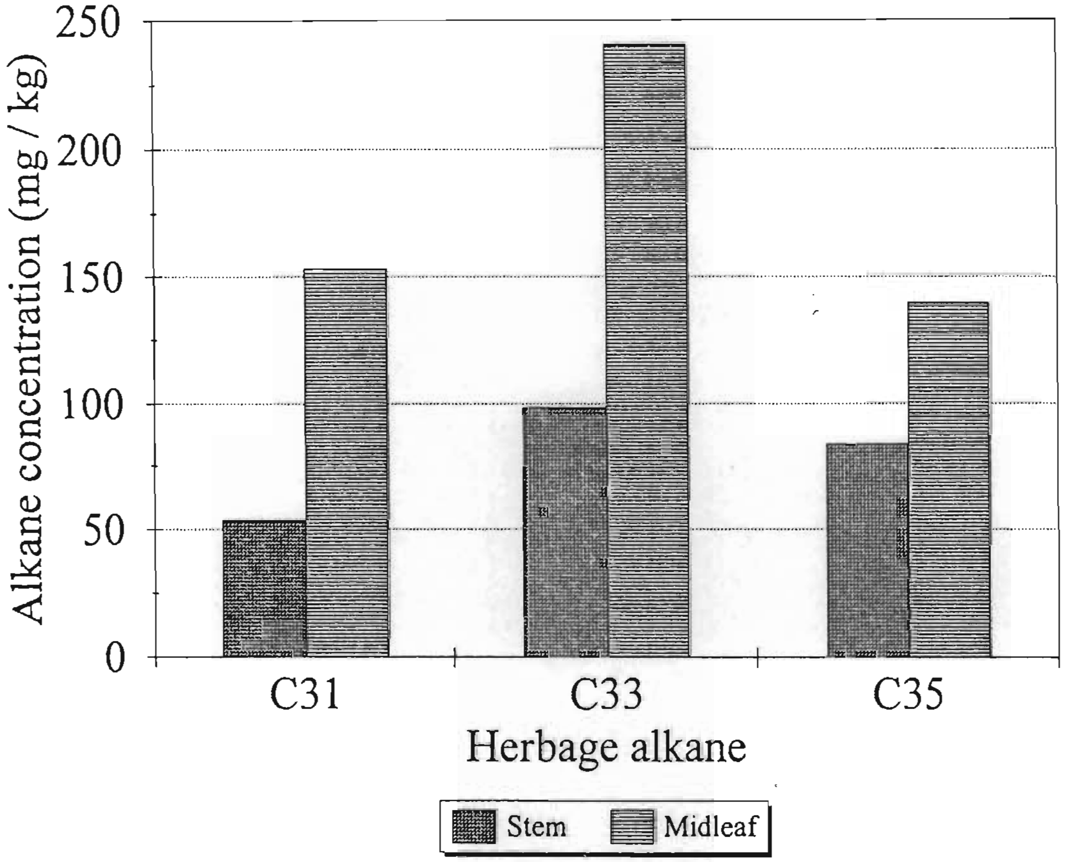

**Figure 1.2.** The concentrations of the $C_{31}$, $C_{33}$, and $C_{35}$ herbage alkanes in the leaf, and stem fractions of kikuyu (*Pennisetun clandestinum*) (after Marais, 1995a).

Cattle improve the quality of their diet by actively selecting particular plants in a pasture, and by consuming the more favourable parts of the plants available. Rutherford (1982) showed that grass leaf was by far the largest individual proportion of the diet at all times of the year with cattle on tropical pastures. Grass leaf as a percentage of total consumption varied from 36% to 69%, whilst the leaf proportion of the total pasture on offer was never more than 20%. Dugmore *et al.* (1991) found similar trends with steers on kikuyu pasture, and went so far as to suggest that, when the quantity of leaf in the available diet is low, the animals preferred to restrict intake rather than increase the quantity of stem in the diet. This view was shared by Minson (1981) for other tropical pasture species. A possible explanation for the selection of leaf over stem lies in the shorter rumen retention time of leaf in the reticulo-rumen associated with a larger surface area, lower grinding energy, and lower density than stem material (Minson, 1981). In mature temperate and most tropical swards, there are large physical differences between the leaf and stem fractions (Minson, 1990).

The correlation between the herbage on offer, and that consumed by the animal is of a more complex nature than that described by differing favourability of plant components alone, and it would seem that chemical components of the herbage on offer may influence dietary selection. It is suggested that the material eaten, when compared with that on offer, usually has a higher content of nitrogen, phosphate and gross energy, but is lower in fibre content (Arnold, 1985), impying a selection by the animals towards younger, less mature leaf material. Dugmore *et al.* (1991) demonstrated that steers grazing kikuyu select for a level of CP in the diet of 14%, whereas the mean CP content over several seasons in the same area recorded in a previous trial (Dugmore and du Toit, 1988) was 18.7%. Differences in chemical composition between the leaf and stem fractions have been observed. Bredon *et al.* (1967) showed that in a mixed tropical grassland in Uganda, all of the grass species studied had higher concentrations of CP and lower concentrations of CF in the leaf fraction than the relative fractions in whole plants. Dugmore *et al.* (1991) confirmed these differences between leaf and stem for kikuyu pasture, although differences between the relative fractions in leaf and stem appear to be small compared to many other tropical species. It is also known that the digestibility of the leaf component declines with advancing maturity (Bransby, 1988). The most probable reason for this is increasing fibre content. Thus, if animals are attempting to improve the quality of their diets by selecting for greater or lesser concentrations of specific chemical components, (relative to the mean concentrations of these chemical components on offer in the herbage) then selection between leaf and stem and between young and mature leaves may be an aid to achieving this goal.

It is, thus, clear that dietary selection by cattle grazing tropical pastures may cause the fraction of material ingested by the animal to be different in both leaf to stem ratio, and in the maturity of its components relative to the mean of the herbage on offer. The magnitude of errors in intake calculations arising from this source, when using the double alkanes technique, will vary depending on the grazing situation and the accuracy of sampling of the herbage. Laredo *et al.* (1991) stated that errors in intake estimation when using the double alkanes technique will tend to increase when the forage is strip- or ration-grazed.

Oesophageal fistulation (Van Dyne and Torell, 1964) may help to provide a more representative sample of the herbage consumed by the animal. However, the greatest problem with this approach is the short sampling period (Bredon and Short, 1971). These researchers claimed that, if the sampling is carried out in the morning, the selection results will probably be lower than those of the full day's grazing, whilst sampling in the afternoon will tend to show a higher selectivity than the day's average. It was also demonstrated by Vulich *et al.* (1993), that there were no significant differences ($P > 0.10$) in the n-alkane concentrations among samples obtained by clipping, hand plucking, or those obtained from pooled extrusa samples via the osophagus (in a trial with sheep grazing *Lolium perenne*). In the same trial the approximate 80% confidence interval estimate of the proportionate bias in estimated intake arising from sampling variation in herbage $C_{33}$ concentration was shown to be from -0.07 to +0.07 when $C_{33}$ was estimated using three samples (where the coefficient of variation (CV) was 0.05); about 35 samples daily would be required to yield an interval of - 0.02 to + 0.02. A possible future improvement, regarding herbage sampling, lies in the use of radio-controlled fistulas (Raats, 1995) which allow sampling to be done throughout the day without penning the animals (Marais, 1995b).

### *1.1.3.3 Standardization of intake relative to liveweight*

It was shown previously that intake in growing animals increased through to maturity. It would seem that this increase in intake is more a function of increasing body mass than age. It should, however, be noted that the nutritional requirements of growing cattle for a given growth rate are higher at a fixed mass for breeds of smaller mature mass relative to breeds of larger mature mass. (ARC, 1980). This is due to them being at differing stages of maturity. Thus intakes of the earlier maturing breeds will have to be higher to achieve an equivalent growth rate. When comparing intakes of a given diet between trials, it is clearly necessary to standardize intakes relative to liveweight. A common method of doing this is to express intake per kg liveweight to the power of 0.75, defined as metabolic body mass (Mentis, 1981). Intake of kikuyu by penned animals in various trials has been shown to vary between 23.4 and 78.7 g/kg $LW^{0.75}$ (Joyce, 1974), whilst with grazing steers Pattinson (1981) found that intake varied between 53.35, and 107.61 g/kg $LW^{0.75}$ for summer, and winter respectively. Unfortunately there is little accurate information available regarding the intake of kikuyu in the grazing situation.

### *1.1.3.4 Alkane administration procedures*

Several methods have been proposed for the preparation and administration of n-alkanes to cattle and sheep. The two most commonly used techniques are the use of alkanes impregnated into shredded paper and the suspension of alkanes in gelatin capsules. Dove *et al.* (1989b) found no significant differences ($P > 0.05$) in faecal recoveries of alkanes when using capsules containing shredded paper or gelatin. However, it was suggested by Dove and Mayes (1991) that, whilst the coefficient of variation (CV) for pellet alkane content in the data from Mayes *et al.* (1986a) was between 2 and 5%, using gelatin capsules may reduce CV to as little as 1 to 2%. Thus, there seems to be no difference between the two methods of administration in the quantitative passage of alkanes through the gut. However, the gelatin capsules may allow for slightly higher accuracy in the quantitative administration of the alkane to the animal. The use of gelatin capsules is also a less laborious approach than the use of shredded paper. Mayes *et al.* (1986a) showed that the addition of palmitic and stearic acids to the diet as emulsifying agents did not improve faecal recovery of alkanes except in the case of $C_{27}$. It was concluded that, whilst additional emulsification agents are not necessary for accurate intake estimation, modification of the method of administration could lead to increased accuracy in the estimation of intake.

Vulich *et al.* (1991) simplified the gelatin capsule preparation by coating the marker alkane onto cellulose fibre in a rotary evaporator at reduced pressure and at 40°C. The required amount of alkane-coated cellulose could then be weighed out directly into each gelatin capsule. It was then shown that the method of supplying the dosed n-alkane to animals (pellets or capsules) had no effect on the accuracy or precision of the herbage intake estimates. The CV for alkane content in the capsules produced was 1.7% for both the $C_{32}$ and $C_{36}$ alkanes. Marais *et al.* (1995) suggested that the administration of n-alkanes in a suspension by means of a dosing gun or syringe would be an even simpler technique. It was proposed that the dosed alkane be coated onto finely milled, dried, kikuyu grass (*Pennisetum clandestinum* Hochst), which was then placed in a suspension containing xanthan gum which acts as a viscosifying agent to retain the milled grass particles in suspension. The suspension could then be dosed directly to the animal at fixed volumes via a syringe or dosing gun. It was found that the CV for the alkane content of the coated grass was 2.27%, and the CV of the alkane content of the doses was $< 2.4\%$.

At least six days of dosing with alkanes should be allowed before commencing faecal sampling. This was demonstrated by the fact that the ratios of herbage odd-chain length alkanes to dosed even-chain length alkanes were significantly higher ($P < 0.05$) for the first five days of faecal collection than for the mean values from days five to ten (Mayes *et al.*, 1986a). Clarification regarding the frequency of dosing of alkanes in cattle is required. As mentoned earlier, diurnal variation in faecal alkane ratios in dairy cattle have been demonstrated to be greater with once-daily compared to twice-daily dosing (Dillon and Stakelum, 1989). A future development which may be of considerable aid in this regard is the use of slow release technology, similar to that already used for the administration of chromic oxide (Dove and Mayes, 1991).

### 1.1.4 Accuracy of measurement of intake and digestibility

Precision of intake estimates relative to actual intake using the double alkanes technique are variable between different trials (Table 1.2). However, these estimates are consistently more reliable than those obtained from previous methods of intake estimation. There is general agreement that the highest accuracy of intake estimation is obtained using the $C_{33}$-$C_{32}$ alkane pair in sheep (Mayes *et al.*, 1986a; Mayes *et al.*, 1986b; Vulich *et al.*, 1991), and in cattle (Mayes *et al.*, 1986c; Dillon and Stakelum, 1988).

Over- or under-estimation of intake in stall-fed animals may be related to differing faecal recoveries of dosed and herbage alkanes. This is consistent with the faecal recoveries of $C_{32}$ and $C_{33}$ being very similar. Using equation (6), it can be calculated that a difference of three percentage units in faecal recoveries of the alkane pair used will lead to a 4.9% error in the estimation of intake (Dove and Mayes, 1991). It is interesting to note that while Vulich *et al.* (1991) did not agree with the concept of increasing faecal recoveries with increasing carbon chain length, they still achieved the most precise estimates of intake with the $C_{32}$-$C_{33}$ alkane pair.

**Table 1.2.** Percentage over- or under-estimation of intake using the double-alkanes technique in cattle and sheep with various alkane pairs; (fresh herbage was fed in all trials).

| | Various alkane pairs used to estimate intake | | | |
|---|---|---|---|---|
| Researchers | $C_{27}$-$C_{28}$ | $C_{29}$-$C_{28}$ | $C_{31}$-$C_{32}$ | $C_{32}$-$C_{33}$ |
| Mayes *et al.* (1986a) | -7.6 | -3.5 | -4.5 | 0.0 |
| Mayes *et al.* (1986b) | | | | -0.1 to +0.4 |
| Mayes *et al.* (1986c)[1] | | | | -1.7 |
| Vulich *et al.* (1991) | | | -8.0 | +3.0 |

[1] cattle used in trial, otherwise sheep.

With animals in a grazing situation, it is obviously relatively difficult to assess the accuracy of intake estimates due to the fact that actual intake is unknown. It would seem likely, however, that errors in the estimation of intake will be greater than with stall-fed animals, due to the fact that it is more difficult to obtain a representative sample of the herbage consumed by the animal. As discussed earlier this source of error may be intensified by certain grazing systems, and may also vary between pasture species. Dove *et al.* (1989a) compared intake estimates obtained using the double alkanes technique with sheep on pasture against intake estimates using the chromic oxide technique on the same sheep over the same period. Different stocking rates were used between treatments to stimulate different levels of intake. It was found that, at high stocking rates, where intakes would have been relatively lower, the alkanes method gave significantly higher ($P < 0.01$) estimates of intake than the chromic oxide method, whilst the reverse was true at low stocking rates ($P < 0.02$). The authors argued that the alkanes technique was more accurate due to the fact that it allowed for the effect of level of intake on herbage digestibility. This was supported by the fact that *in vivo* digestibility estimates using $C_{33}$ (equation (3)) were higher than the *in vitro* value when intakes were low, but lower than the *in vitro* value when intakes were high.

It can be deduced from equation (3) that incomplete faecal recovery of the chosen herbage odd-chain length alkane leads to an overestimate of indigestibility, and, hence, an underestimate of digestibility. It would., thus, seem logical that, if faecal recoveries of n-alkanes do indeed increase with increasing carbon chain length, one would want to measure digestibility using the longest odd-chain alkane available in sufficient quantity in the herbage. Dove *et al.* (1989b) showed that faecal recoveries of certain alkanes may be different between trials, and concluded that, in the absence of recovery data, it would not be valid to use the faecal levels of natural alkanes to estimate herbage digestibility, as a single recovery value for any alkane cannot be assumed. Piasentier *et al.* (1989), however, found that while digestibility was always underestimated in sheep due to the faecal recovery of $C_{33}$ being 83.4%, the recovery of $C_{33}$ was constant and its estimation of digestibility had a correlation of 0.839 with apparent digestibility. Wilkinson and Mackie (1988), however, found that the use of n-alkanes slightly overestimated digestibility in cattle. The explanation for this is not certain. It would, thus, seem that while the *in vivo* based digestibility estimates obtained using herbage alkanes enable more accurate estimates of intake using the double alkanes technique than the previously used *in vitro* estimates, not enough is known about the causes of variation in faecal n-alkane recoveries to allow their use as independent absolute digestibility estimates. However, it would seem logical that these digestibility estimates could be a useful tool for comparative purposes under conditions where faecal recovery values of alkanes are likely to be similar, as it has been shown that the *in vivo* estimates of digestibility have the ability to adjust for differing levels of intake.

### 1.1.5 Summary

Although the use of n-alkanes to estimate herbage intake and digestibility is a relatively new concept, results thus far are encouraging, suggesting that intake may be estimated with a higher degree of accuracy than previously used methods. There are however limitations with the double alkanes technique and considerable research needs to be carried out on certain aspects in order to minimize errors related to n-alkane based estimates. The most limiting aspects of the technique at present would are as follows:

(i) faecal recoveries of n-alkanes in cattle are less well known and appear to be more variable than in sheep, probably because techniques have been less well researched in cattle than sheep;

(ii) obtaining a representative sample of the herbage in a grazing situation is difficult, especially with tropical pastures such as kikuyu. The use of remote controlled fistulas in the future may allow greater accuracy in this respect;

(iii) the accuracy of the technique in grazing situations needs to be more thoroughly assessed, as few results pertaining to trials of this nature have been published; and

(iv) the factors which could influence faecal recoveries of n-alkanes such as the age, physiological state, and species of animal must be more thoroughly understood.

The alkane method for estimating intake allows actual digestibility in individual animals to be determined, and, hence, estimates of intake may be calculated for individual animals (Dove and Mayes, 1991). This leaves the ranking of animals on the basis of efficiency of utilization of grazed herbage wide open as an exciting area of future research. While there would appear to be a need for the technique to be more thoroughly calibrated (especially using cattle, and on tropical pastures), it would seem that the technique should be reliable for comparative purposes.

## 1.2 An Overview of Growth and Maturity in Cattle

### 1.2.1 Introduction

Fowler (1968) referred to growth as having two aspects. The first is measured as an increase in mass per unit time, and the second involves changes in form and composition resulting from differential growth of the component parts of the body. An increase in mass per unit time is accomplished through two major processes, the first being an increase in cell numbers referred to as hyperplasia, and the second being an increase in cell size referred to as hypertrophy. Changes in form and composition relate to differential growth of individual tissues within the animal. As carcass composition studies are expensive in both material and labour (Pommeroy, 1978), it is important to have an understanding of the differential growth patterns of various tissues within the animal so that growth phenomena can be compared between animals without using slaughtering techniques.

A major problem when studying growth phenomena seems to be the choice of a suitable scale when making comparisons between individuals, or component parts within the individual.

Comparisons made at equal weight do not take into account the differing maturity patterns of tissues within individuals relative to the maturity pattern of the whole (Butterfield, 1988). Mature mass is also not given proper consideration. It is for these reasons that stage of maturity will be examined in some detail in this chapter, as a useful scale for making growth comparisons.

## 1.2.2 Basic concepts of growth

### *1.2.2.1 The growth curve*

Webster (1989) expressed the opinion that during uninterrupted growth, body weight and related parameters increase along curves that proceed in an approximately sigmoid fashion (Figure 1.3) to an asymptotic value which represents maturity. Butterfield (1988) described the first stage of this growth curve up to the stage where the growth starts to decline as the "survival phase". "During this stage accelerating weight gain, and intensive ferment of growth of internal structures, help ensure size and form of the animal to allow entry into the next phase. The final phase of growth is referred to as the maturing phase, because decelerating growth continues through to maturity".

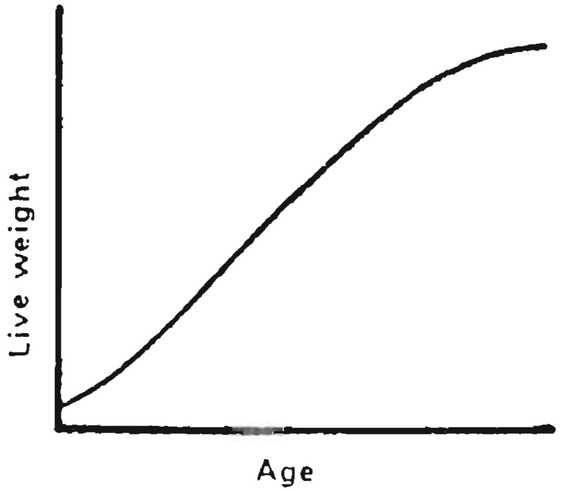

**Figure 1.3.** A typical growth curve of cattle (after Berg and Butterfield, 1976).

### *1.2.2.2 Growth of individual tissues*

It is clear that the growth curves of individual tissues, and organs are also sigmoidal, but because tissues develop at different times the individual growth curves cannot be superimposed. In other words, if an animal were to be considered at a given mass during growth, the development of one tissue may be increasing together with a concomitant decrease in the development of another tissue. The net result of these patterns leads to changes in the proportions of tissues as the animal grows. Hammond (1932) (cited by Fowler, 1980) described these changes in proportion as resulting from :

(i) components having different size when differentiated in embryo;
(ii) components having different asymptotic weights; and
(iii) components having growth curves not necessarily in phase with one another.

Hammond found the order of development between the main tissues to be first bone, then muscle, and finally fat (Figure 1.4). These tissues can, thus, be referred to as early or late maturing tissues, depending on the sequence in which they reach their maximum absolute growth rates. Fat, for example, would clearly constitute a late maturing tissue.

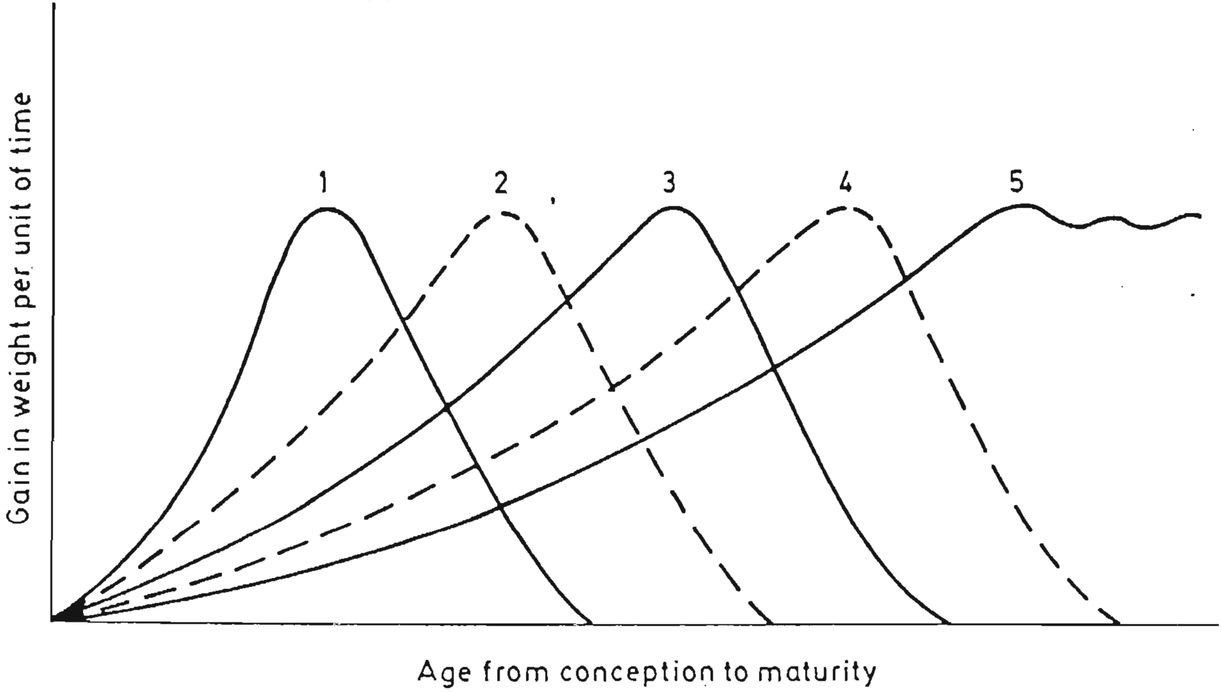

**Figure 1.4**. The relative maturity of tissues as indicated by the time from conception at which they reach their maximum absolute growth rates. The numbers 1, 2, 3, and 4 represent the order of maturity of tissues as nervous tissue, bone, muscle, and fat respectively. The maximal rate of feed intake is represented as 5 (after Hammond, 1932 cited by Fowler, 1980).

Berg and Butterfield (1976) expressed the opinion that after puberty, animals grown on a positive plane of nutrition reach a stage where muscle growth slows relative to fat deposition. Therefore, within a given breed and sex, heavier animals tend to be fatter. These workers also described fat as the most variable tissue in the carcass, the amount deposited being influenced by plane of nutrition, maturity, breed, and sex of the animal. Figure 1.5 clearly shows the changing proportions of muscle, fat, and bone as carcass weight increases. The proportions of muscle, and bone tend to decrease, while fat increases with increasing carcass weight.

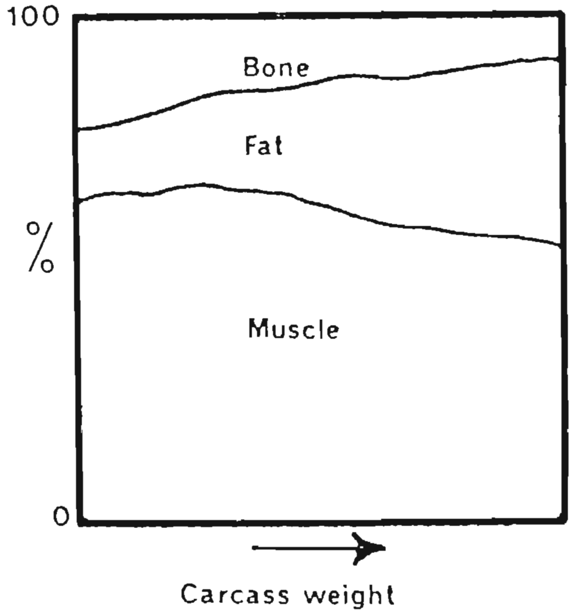

**Figure 1.5**. Percentage muscle and fat in a typical carcass during growth (after Berg and Butterfield, 1976).

The peak growth rates of various tissues have been demonstrated to be dependent on the plane of nutrition. Furthermore, a low plane of nutrition would seem to delay the development of later maturing tissues, such as fat, more than the development of earlier maturing tissues, such as bone (McMeekan, 1940). Consequently, the development of individual tissues can be differentially regulated by changing the plane of nutrition at different stages of growth. McMeekan (1940) also implied that body composition can be changed by altering the shape of the growth curve of the whole body, which is dependent on the shapes of the growth curves of individual tissues.

Huxley (1932) presented the model of constant differential growth ratio, often referred to as the allometric equation, where if over a given period of growth, the specific growth rates of two parts, x and y, have a constant ratio, b, between them, that is :

$$\frac{(dy / dt)}{y} = b \frac{(dx / dt)}{x} \tag{7}$$

when the growth of one part relative to another can be expressed as:

$$\log y = b \log x + \log a \tag{8}$$

or:

$$y = a x^{b} \tag{9}$$

where b is referred to as the allometric coefficient.

Huxley studied the correlation in terms of part, 'y' on the whole animal, 'x'. The theory associated with this formula implied that the form of an animal depends solely on its absolute size and not upon the length of time that it has taken to reach that size (Elsley *et al*,. 1964). Three possible situations arise:

(i) 'b' > 1 implies proportion of y to x increases as the weight of x increases;

(ii) 'b' = 1 implies percentage growth rates are the same, and the proportion of one tissue to the other remains constant over a given range of weight, or;

(iii) 'b' < 1 implies that as x increases, the proportion of y to x decreases (Fowler, 1980).

Huxley concluded from his studies that it is body weight that determines the size of individual components. This is an opposing view to that suggested by McMeekan (1940). The view of McMeekan (1940) suggested that allometric interactions are disturbed by changes in the plane of nutrition. That is, earlier maturing tissues get preference in times of nutritional stress. Elsley *et al.* (1964) re-analysed the data of Huxley and concluded that, if fat was excluded from the analysis, in most cases the allometric equation would give a good fit to the data. This agrees with the description given by Berg and Butterfield (1976) of fat as the most variable tissue in the carcass.

### *1.2.2.3 Nutritional influences*

"Nutrition is by far the most important environmental influence on growth and development, before and after birth" (Widowson and Lister, 1991). It would seem that an adequacy of protein and energy determine growth if the requirements for all other essential nutrients are met. The amounts and proportions of protein and energy in the diet are critical. Maximum rates of protein deposition do not occur when energy is limiting or vice versa (Elliott *et al.*, 1964). The proportions of protein and energy in the diet can also influence intake (Crabtree and Williams, 1971). The correlation between protein and energy is thus a complex one. It would seem that there is an optimum ratio of protein to energy in the diet that will allow an animal to reach its genetic growth potential, if all other nutritional requirements are met.

It should not be forgotten that an animal must first meet its demands for 'maintenance' before the energy from the feed consumed can be used for the process of growth. Gill and Oldham (1993) expressed concern about these maintenance requirements being expressed separately from production as maintenance energy costs are influenced by recent and current growth rates. It has been shown that animals expected to reach higher mature weights grow at faster rates. Hence, factors such as mature mass may influence the maintenance energy requirements of an animal at any specific point in time.

Whilst many workers are of the opinion that total feed intake determines the size to which animals grow, some such as Webster (1989) disagree, claiming that animals grow to a particular size which regulates intake at the outset. Fitzhugh, and Taylor (1971) expressed the opinion that weight increase seemed to be a function of food intake rather than time and that, as the animal approaches maturity, liveweight increases decline relative to food eaten. Butterfield (1988) plotted the correlation between degree of maturity, and efficiency (Figure 1.6).

It has been demonstrated that as cattle mature there is an increasing tendency to deposit fat rather than lean tissue, and hence it would seem logical that as liveweight increases rate of gain in body weight, and growth response to increasing concentrations of dietary protein will tend to decline. The reason for this being that the energy cost of synthesising body protein from dietary protein is less than that of synthesising body fat from dietary protein. Lobley *et al.* (1980) found that synthesis of skeletal muscle contributed only 25% of the total body protein synthesis, whilst at least 50% of daily N retention is as muscle protein. This implies that the efficiency of deposition (i.e. protein deposited : protein synthesised) is much higher for muscle than any other tissues.

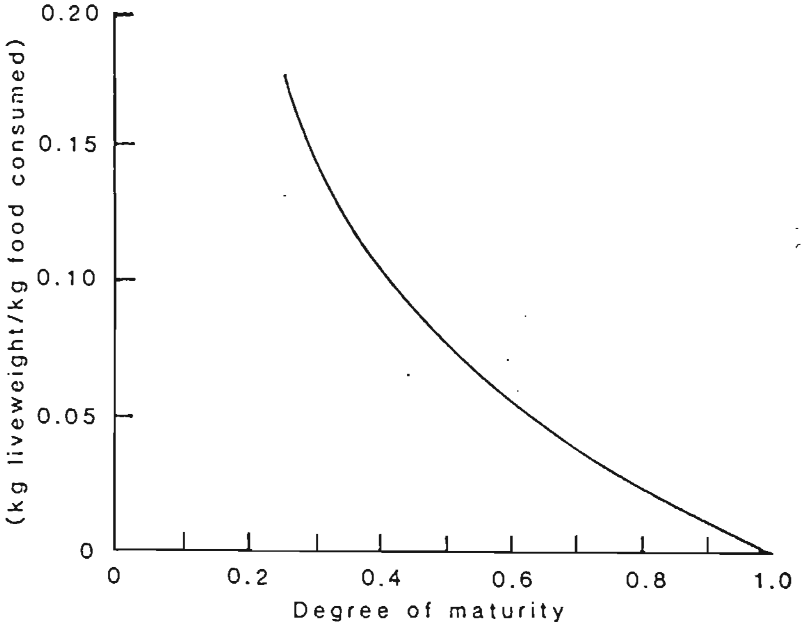

**Figure 1.6.** Food efficiency during progress to maturity of a 100 kg ram fed *ad lib.* on a highly nutritious food (after Butterfield, 1988).

Energy requirements for growth can be separated into two components. One is the requirement of substrates from which to form the components of the new tissue, and the other is the extra energy needed to meet the metabolic cost of growth (Millward *et al.*, 1976). The first requirement is absolute. As previously demonstrated, the maximal absolute growth rates of the various tissues occur at different times, and hence nutritional requirements are variable as the composition of liveweight gains change over time. Thus weight gain in older animals tends to involve the deposition of more energy because of the higher fat content of these gains as the animal approaches maturity. It should be noted here that if more protein is supplied in the diet than is needed by the tissues for growth then the excess amino acids are deaminated and used as energy sources (Blaxter, 1962). The retention of amino acids in the body can be expected to be an efficient process because the only additional energy required is that needed to synthesise peptide bonds which link them together in proteins. If, however, they are deaminated, then energy will be needed to synthesise urea , to excrete urea, and to convert their carbon through the various stages to fat (Blaxter, 1962).

The metabolic cost of growth is that observed as heat production associated with growth. It has been shown that heat production during growth occurs primarily in relation to protein deposition rather than fat (Millward *et al.* 1976). To quote Millward *et al.* (1976), "The fact is that protein deposition should be seen as lean tissue growth, and it is alterations in lean tissue growth that are liable to alter the pattern of heat production. Conservation of lean tissue becomes the priority when intakes are reduced and it is the deposition of lean tissue during growth which causes the developmental changes in metabolism. Thus, it is not surprising that when heat production during growth is partitioned statistically between fat and protein, the deposition of protein should appear responsible for most of it." It would seem however that the requirement of substrates to form the components of the new tissue is more demanding in terms of energy cost than the increased heat loss with the deposition of protein relative to fat. This is proved by the fact that feed intake reaches its highest level after most tissues have finished maturing (Figure 1.4), or at least after they have reached their maximum absolute growth rates. Hence, efficiency of feed conversion of into body weight declines as the animal reaches maturity, and hence as fat deposition increases. Animals, well advanced in the fattening stage, have very slow muscle growth, and this, coupled with the high energy cost of depositing fat and high maintenance costs of a heavy animal, results in a very low biological efficiency for muscle growth. The protein mass in the body is nearly always associated with a concomitant deposition of fat, and that it is only at very low growth rates that the proportion of fat in the gains may become negligible (Blaxter, 1962).

### 1.2.3 Basic concepts of maturity

"Comparisons made at the same metabolic age or at the same degree of maturity are independent of adult size" (Taylor, 1985). Hence, the motivation for comparing individuals on these scales, rather than on an equivalent age or mass basis.

#### *1.2.3.1 Mature mass, stage of maturity and time taken to mature*

Taylor (1985) gave a formal definition of mature mass as "the body weight of a normally grown, skeletally mature, normally active adult male, maintained in a state of body weight equilibrium on a standard diet, in a thermo-neutral, disease-free environment, with, or adjusted to, a chemical body fat of 20%". Taylor (1965) claimed that in certain instances mature liveweight can provide a comprehensive measure of mature size, however, when different breeds or individuals within a breed are compared, the effect of differences in nutrition and environment can become relatively so great that unqualified use of mature liveweight can become almost worthless. The estimation of an animal's mature mass is one of the greatest problems when making comparisons on the basis of maturity. It is clear that the closer the correlation between the two individuals being compared, the greater the need for accuracy in estimating mature mass.

The stage of maturity (P) of an animal at a given mass (W), and having a given asymptotic mature mass (A) can be defined as:

$$P = \frac{W}{A} \tag{10}$$

'A', is referred to as the asymptotic weight because the sigmoidal growth curve is asymptotic to it. Brody (1945) considered an animal to be mature when it reached 98% of its asymptotic weight. It should be remembered that 'A' does not necessarily refer only to mature liveweight. It may also measure the mature size of body components, and the unit of expression need not be weight. Fitzhugh and Taylor (1971) found that the size of an animal (at some stage of its development) could be split into two components, one, 'A', describing mature size, and the other, 'P', describing the proportion of mature size reached at the stage in question. Hence, equation (10) could simply be rewritten as:

$$W = PA \tag{11}$$

Fitzugh and Taylor (1971) also showed maturing rate to be growth rate relative to mature size through the following equation :

$$\frac{dp}{dt} = \frac{1}{A} \cdot \frac{dw}{dt} \tag{12}$$

This led Fitzhugh and Taylor (1971) to the conclusion that :

(i) an animal's maturation rate, like its growth rate, will change continuously through the growth period; and

(ii) the distinction between slow and fast growing animals is not equivalent to the distinction between slow and fast maturing animals.

### *1.2.3.2 The use of the relative maturity coefficient (q)*

Butterfield *et al.* (1983) fitted a quadratic curve of the degree of maturity of body components at slaughter against the degree of maturity of shorn full liveweight at slaughter in sheep. This quadratic curve was constrained to fit through the origin (0,0), and the point (1,1). This is consistent with the components being zero size when the animal is zero size, and the components being mature when the animal is mature. Hence, in, the quadratic equation :

$$y = p + qx + rx^2 \tag{13}$$

p = 0, and r = 1 - q.

Thus the equation could be rewritten as:

$$y = qx + (1-q)x^2 \tag{14}$$

As with Huxleys (1932) 'b' values three possible situations arise from the q values :

(i) 'q' > 1.0 implies a lesser rate of growth or "low impetus" relative to the whole animal, and therefore a declining portion of the whole.

(ii) 'q' = 1.0 implies the component is growing at an equivalent rate to the whole, or "average impetus". Hence the proportion of the part to the whole remains unchanged.

(iii) 'q' < 1.0 implies a greater rate of growth or "high impetus" relative to the whole animal, and therefore an increasing proportion of the whole.

The great advantage of Butterfield *et al's* (1983) 'q' values over Huxley's (1932) 'b' values is that the 'q' values are additive while the b values are not. To quote Butterfield *et al.* (1983) "this implies a 'q' value can be calculated for the sum of a number of components from the sum of individual 'q' values weighted according to the proportion of the mature weight of the individual components relative to the mature weight of the sum of the components".

The growth of tissues described earlier can now be re-examined using degree of maturity as a scale for comparison.

### *1.2.3.3 Growth revisited (using the maturity approach)*

The maturity patterns of muscle, bone and fat in a Merino ram are shown in Figure 1.7. Muscle and bone have similar patterns of maturity, both having low growth impetus (i.e. they have 'q' values > 1.0), whilst fat has a very different maturing pattern, having a very high growth impetus (i.e. a 'q' value considerably lower than 1.0). This agrees with the relative maturity of tissues illustrated in Figure 1.4. The important concept to note, however, is that we now have a means of comparing the maturity of different components relative to the maturity of the whole. This effectively allows one to remove the erroneous assumptions made by comparing animals at fixed mass, when their mature weights differ. A given tissue will usually have a similar, but not identical maturity pattern in two different animals, and this may result in changing proportions which are closely related to stage of maturity. Hence, when two animals of different mature mass are compared, at equivalent weight, differences may arise due to stage of maturity and mature composition (Butterfield, 1988).

A similar principal applies when comparing two individuals at equivalent age. Brinks *et al.* (1964) showed individual differences in size at any age to be genetically highly correlated with size at other ages. Thus, size differences between immature individuals of the same age, and environmental history largely reflect differences in mature size (Fitzhugh and Taylor ,1971). Fitzugh and Taylor (1971) claimed that size at any age can be partitioned into two components:

(i) one measuring the effect of proportionality to mature size; and

(ii) one measuring the extent of deviations from proportionality to mature size resulting from individual differences in rate of maturing, or earliness of maturing.

Hence, when comparing two individuals at the same age, one will still have differences due to stage of maturity caused by differing mature masses, as well as individual differences in rate of maturing. On a tissue level, differences in rate of maturing will be related to mature composition of the whole.

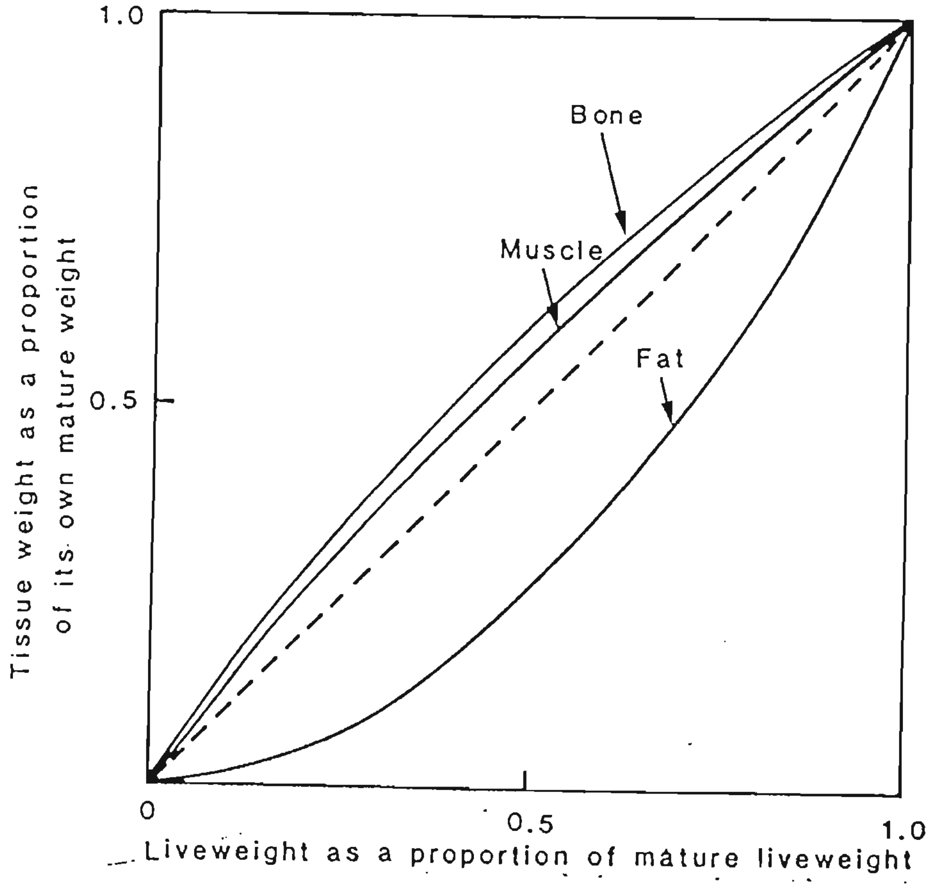

**Figure 1.7.** Maturing patterns of muscle, bone and fat in a Merino ram (after Butterfield, 1988).

### 1.2.4 Breed differences in growth and maturity

The topic of breed differences in cattle is a controversial one, often involving somewhat questionable results due to the fact that small numbers of animals are frequently placed under specific environmental conditions which may favour one breed over another. The ranking of different breed types on the basis of performance is beyond the scope of this review. The aim is rather to highlight some observed differences in growth and body composition in trials where earlier- and later-maturing breeds were used. Observed breed by nutrition interactions will be briefly considered, because these could imply that certain breeds may be able to utilize a given diet more effectively than others, which is of considerable relevance.

Thiessen *et al.* (1984) found that after approximately one year of age, the proportion of variation between 12 breeds of cattle was approximately 0.70 for body weight and 0.60 for cumulated voluntary intake. Changes in these traits can, therefore, be brought about more effectively by selection between breeds rather than within breeds.

#### *1.2.4.1 The influence of breed on growth of the whole animal*

It is generally accepted that breeds growing towards a larger mature mass grow at a faster rate. Keane and More O'Ferrall (1992) clearly showed that Simmental x Friesian steers grew faster during all age intervals from shortly after birth until a mean period of 740 days than Hereford x Friesian steers, when nutrition was identical. Ferrell *et al.* (1978) also found that steers having a capacity for large mature size grew at faster rates than those having smaller mature size. Morgan (1981), however found that Hereford heifers grew at a slightly faster rate (0.46 vs. 0.42 kg/day) than Friesian heifers from weaning (8 months) until 21 months of age. A possible explanation for this is that the higher mothering ability of the Friesian dams allowed for higher growth before weaning in the Friesians. Hence, the Herefords could be said to be expressing a form of compensatory growth relative to the Friesians. It is also possible that the Friesian heifers used in this study were of the smaller framed European type.

This study also showed that Friesian and Friesian cross heifers reached puberty at an earlier age than Herefords and Hereford cross heifers. It would, thus, seem that a high maternal ability of the dam facilitates the early breeding of the heifer progeny. However, when breeds known to be very large in mature size such as the Charolais were crossed to the Friesian dams, age at puberty in the offspring was delayed. This agrees with the findings of Gregory *et al.* (1979) who showed that breed of sire varied age and weight at puberty of heifer progeny from 326 days and 291kg in the case of Pinzgauer heifers to 383 days and 337 kg in Brahman crosses. It seems that there is a definite trend for puberty to be reached at a younger age and lighter mass, in earlier maturing breeds. However, high mothering ability, especially in the case of dairy breeds, may disturb this correlation. Wiltbank *et al.* (1966) confirmed this correlation by showing that Angus and Shorthorn heifers reached puberty earlier and lighter than Herefords. Wiltbank (1966) also showed, from six types of reciprocal crosses, that heterosis increases the rate of maturity. Morgan (1981) similarly determined that reciprocal crosses with Herefords and Friesians showed estimates of heterosis to be 2.6%, and 3.8%, respectively, for average daily gain and liveweight in the heifer progeny. These results were, however, not statistically significant ($P > 0.05$).

Although Ferrell *et al.* (1978) showed that steers having genetic potential for larger mature mass grow at faster rates, they also found feed intake for the larger steers to be higher, leading to similar or less efficient gains. Dry matter intake did not differ between breed groups when expressed on the basis of metabolic body size. However, weight gains expressed on this basis slightly favoured the smaller type steers. This is somewhat surprising since the small-type steers contained a higher percentage of fat and a lower percentage of protein than the large-type steers. Similar results were found by Garrett (1971), who observed a slightly more improved feed to weight gain ratio in Hereford than in Holstein steers. Garrett (1971) attributed these results to a higher maintenance cost of the Holstein steers and a higher energy cost of protein than fat synthesis. It should be noted that Ferrell *et al.* (1978) did, however, conclude that the edible product, protein, produced for a given feed input favoured the larger-type steers. This implies that relatively more feed was being used for fat deposition in the smaller-type steers. It is interesting to note that higher intakes of silage per kg liveweight have been observed in Friesians relative to beef crosses (Keane *et al.*, 1989; Keane and More O'Ferrall, 1992). The reason for this is not known.

#### *1.2.4.2. The influence of breed on body composition*

McClelland *et al.* (1976) showed that "while a large part of between-breed differences in body composition can be accounted for by stage of maturity, useful amounts of variation remain". It was shown earlier in this chapter that within species variation in the maturity patterns of individual tissues is relatively small. Between breed differences in growth rates and earliness of development of tissues, particularly muscle and fat, will, however, be of considerable economic importance to the meat producing industry.

Berg *et al.* (1978a) compared carcass composition and tissue growth among different genetic groups represented by eight sire breeds used in a crossbreeding experiment. They found that sire breed groups did not differ in allometric regression coefficients of muscle on carcass weight but there was a tendency for the fattest breed to have a lower regression coefficient and, the leanest to have a higher regression coefficient, compared with the common regression. This implies that, in general, muscle grew at a similar rate between breeds relative to carcass weight when the extremely early- and extremely late-maturing breeds were excluded from the analysis.

Berg *et al.* (1978a) also studied the regression of muscle on bone and found that, although similar between breed regression coefficients were obtained, the amount of muscle relative to bone differed between breeds (Figure 1.8). There appeared to be no tendency for certain maturity types to have larger amounts of muscle relative to bone. There is, however, disagreement on this point; both Wheeler *et al.* (1989) and Berg and Butterfield (1976) found lower muscle to bone ratios in later-maturing breeds than earlier-maturing breeds. In fact, it would seem that higher muscle to bone ratio is largely an indication of improved conformation or shape (Kempster, 1978), although Butterfield (1988) expressed the opinion that "the influence of muscle to bone ratio on external appearance of both live cattle and their carcases is clearly apparent in the increasing numbers of later-maturing types of cattle now being used in many countries". Berg and Butterfield (1968) showed that muscle to bone ratio for the individual tended to increase with increasing carcass weight. This implies that the 'b' values for the regressions in Figure 1.8 are greater than 1.0 because the regressions of muscle and bone against carcass weight have 'b' values greater than 1.0. Muscle and bone show a high correlation because they are both components of increased size (Berg and Butterfield, 1976). Berg and Butterfield (1976) indicated that differences in the regression of muscle on bone and in muscle to bone ratio indicate genetic influences in the relative growth of these tissues. It was suggested that the amount of muscle relative to bone should be amenable to selection.

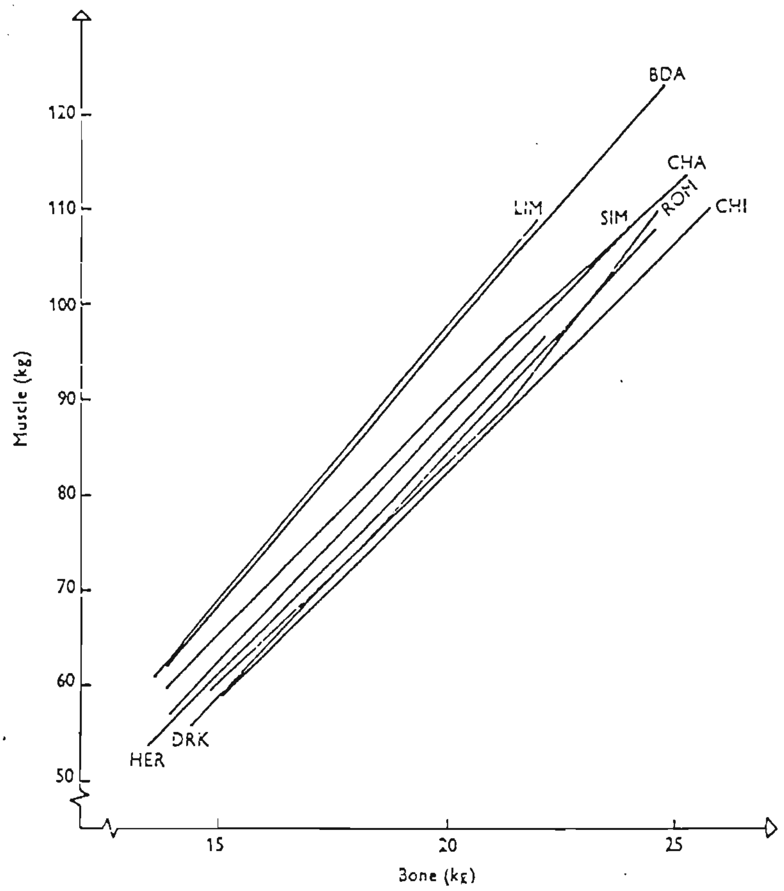

**Figure 1.8**. Growth of muscle relative to bone in young bulls by sire breed plotted from actual slaughter group means (after Berg *et al.* 1978a).

One of the more useful regressions for making comparisons on the basis of fat deposition is the comparison of fat against the relative fat-free weight of the carcass. It is clear that the earlier-maturing breed types in this correlation will fatten at lighter fat-free weights than the later maturing breed types. Interestingly, however the breed regression lines may not necessarily be parallel (Figure 1.9). This implies that genetic differences may occur in both earliness of fattening relative to weight or size of the animal, and also in the rate of fattening relative to increase in weight of muscle plus bone through the fattening phase (Berg and Butterfield, 1976). Berg *et al.* (1978a) showed that regressing fat against various size dimensions resulted in was homogenous allometric regressions among sire breed groups. However, the breed group with the least fat had lower regression coefficients, indicating a tendency to slower fattening which supports the findings of Berg and Butterfield (1976). Wheeler *et al.* (1989) supported this theory by showing that fat in the longissimus muscle in later-maturing cattle increased at a slower rate than in earlier-maturing cattle. Fat in the longissimus muscle was, in fact, increasing at a faster rate than fat in other depots in the carcasses of the later-maturing cattle.

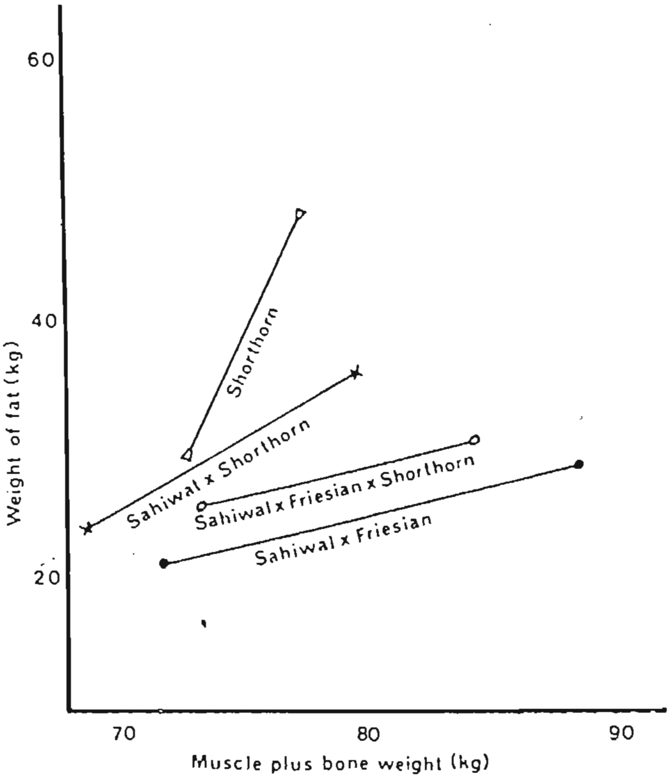

**Figure 1.9.** Fattening patterns of a breed and crossbreeds relative to muscle plus bone weight (after Hayman and Gardner, 1972, cited by Berg and Butterfield, 1976).

The relative growth of fat in the carcass, as defined by earliness of fattening and rate of fattening, clearly has important economic implications in a market where low fat levels are desirable. Keane and More O'Ferrall (1992) showed that, in Europe where dairy-bred cattle are the main source of beef, the crossing of Friesian / Holstein dairy cows with a late-maturing animal type, the Simmental, rather than the traditionally used Friesian x Hereford sire (relatively earlier-maturing) would permit carcass weight of the progeny to be increased by a factor of 0.3 without any increase in carcass fatness. Alternatively, the Simmental progeny would have a fat content of only 0.7 that of the traditional progeny at similar carcass weights. Wheeler *et al.* (1989) found that, although cattle became fatter the longer they were fed, the later-maturing cattle tended to have fairly constant fat levels after 77 days on feed, whereas the earlier-maturing cattle continued to fatten. The later-maturing cattle produced carcasses with about 50% less fat when slaughtered at a fixed age and had between 2 and 10% more saleable product than the earlier-maturing cattle. It was concluded that low-fat beef could be produced better by cattle of a late-maturing breed type.

Bone has the lowest growth impetus of all tissues in the carcass, implying that its weight as a proportion of total carcass weight decreases as the animal grows towards maturity (Figure 1.5). Existing evidence suggests that the growth rate of bone is a relatively inflexible characteristic. Fourie *et al.* (1970, cited by Butterfield, 1988) found significant differences in the growth coefficients of bone of different breeds of sheep. They claimed that this was one of the first experiments with domestic animals that established significant within-species differences between breeds in allometric growth coefficients for bone. Berg *et al.* (1978b) showed the differential growth pattern of bone was also similar between breeds by determining homogenous growth coefficients among breed groups for bone in each joint relative to total side bone. Existing evidence suggests that the distribution of bone throughout the carcass is a relatively inflexible characteristic which varies little over the range of weights at which beef cattle are normally slaughtered (Kempster, 1978).

### *1.2.4.3 Breed interactions with nutrition*

Breed differences in growth and carcass composition at a fixed level of nutrition tend to increase with increasing feeding intensity. It is known that breed differences in growth are closely related to mature size, provided that a sufficient energy supply is given. On the other hand, breed differences get smaller as feeding intensity and / or fattening period declines (Langholtz, 1978).

Prior *et al.* (1977) found interactions between both dietary energy density and protein concentration, and breed type. High dietary energy increased the rate of fat deposition to a greater extent in small-type steers than large-type steers. High protein concentration in the diet resulted in greater fat deposition in the larger-type steers, i.e. those having genetic potentials for higher growth rates. Ferrell *et al.* (1978), however, found no significant ($P > 0.05$) interactions between breed type and dietary energy density or protein content. Breed differences expressed in terms of feed efficiency (amount of nutrients per kg liveweight gain), are of the same order as the differences in daily liveweight gain, being in favour of the faster growing breeds. Ferrell *et al.* (1978) supported this by showing that protein and edible product produced per unit feed intake was greater in larger, faster-growing steers than in smaller, earlier-maturing steers. There is a strong indication that breed differences in growth are mainly due to differences in the animal's daily capacity to retain protein. "This means that at a given feeding level, differences are to be expected between breeds concerning the proportional use of the free metabolisable energy for protein and fat synthesis which in turn lead to the observed breed differences in dressing out percentage, degree of fatness and to a lesser extent of differences in the meat: bone ratio" (Langholz, 1978).

Differences in the comparative digestive powers of *Bos indicus* (zebu) and *Bos taurus* type cattle have been noted by Phillips *et al.* (1960) and Howes *et al.* (1963). Phillips *et al.* (1960) reported an average dry matter digestibility of 67.7% for zebu and 65% for zebu crossbred steers. The explanation for this was claimed to be a shorter rumen retention time in zebus together with a greater fermentation rate per unit of solids. Howes *et al.* (1963) had similar findings, showing that Brahman heifers were more efficient in digesting all dietary components, except ether extract relative to Herefords. Species differences were, however, only significant for crude protein ($P < 0.05$). On low protein diets, Brahmans digested more protein and consumed more dry matter than Herefords. These observed differences could clearly cause variations in growth rate between breeds due to differing efficiencies, especially where low protein diets are fed.

### 1.2.5 Summary

The literature reviewed is summarized in point form.

(i) Tissues develop in a sequential pattern with fat being a relatively late-maturing tissue. Fat is also the most variable tissue in the carcass. Earlier-maturing tissues may be given preference for the allocation of nutrients under times of nutritional stress, and, hence, fat tends to be the most severely affected tissue during times of nutritional stress.

(ii) As cattle mature, their conversion efficiency of feed into liveweight declines. This is due to the increasing proportion of fat relative to protein in the liveweight gains, and an increasing maintenance requirement. It is known that the deposition of fat is a less efficient process than the deposition of protein.

(iii) Different components of the body will tend to have differing "growth impetus", and, hence, these will increase, decrease or remain constant as proportions of the whole. This can be expressed using Huxley's (1932) 'b' values or Butterfield *et al's* (1983) 'q' values. The advantage of using Butterfield's 'q' values is that mature size is taken into account, and hence these values are additive.

(iv) Later-maturing breeds which have larger mature size tend to grow at faster rates than earlier-maturing breeds of smaller mature size. Earlier-maturing breeds reach puberty earlier than later-maturing breeds. Although later-maturing breeds may grow faster than earlier-maturing breeds, their feed intakes tend to be higher, and hence efficiencies tend to be equal or lower. It is possible however that the efficiency of protein deposition may be higher in later-maturing breeds.

(v) Although certain breeds may have higher amounts of muscle relative to bone than others, the actual growth rate of muscle is relatively consistent between breeds. Later-maturing breeds have, however, been reported to produce more edible product per unit intake. Differences between breeds in rate of fat depositiont have been noticed, with earlier-maturing breeds fattening earlier and at faster rates. A later maturing breed has the potential to produce a heavier carcass at a given level of fat than an earlier-maturing breed, or alternatively a carcass of the same weight at a reduced level of fat.

(vi) Bone has a relatively low "growth impetus" and tends to be relatively constant and inflexible in its growth rate.

(vii) It has been reported that increased dietary energy may increase the rate of fat deposition more in earlier-maturing animals than those that are later-maturing, whilst increased dietary protein increases the rate of fat deposition preferentially for later maturing animals. Another reported breed by nutrition interaction is the fact that *Bos indicus* cattle may have greater digestive powers for protein than *Bos taurus* cattle.

To conclude it would seem that at a given age, breed differences in body composition, and therefore, the conversion efficiency of feed into liveweight will be largely influenced by differences between the breeds in their relative stages of maturity. Hence, determination of breed differences in response to a given nutritional regime at fixed age requires some knowledge of mature mass so that the magnitude of this effect can be estimated.

## 1.3 Conclusion

Intake and digestibility of grazed herbage have been measured with a relatively high degree of accuracy using alkanes as internal markers. Further work however needs to be done to test the reliability of the technique on tropical pastures such as kikuyu. Alkanes allow for intake and digestibility estimates specific to individual animals to be obtained. Hence, this technique has the potential to illustrate differences in intake and efficiency with which the grazed herbage is utilized, both between individuals and groups of animals. This could be of considerable benefit, as it would allow individuals or breeds with high levels of intake, and / or efficiency to be identified. Selection could then proceed towards a known target. Kikuyu is a relatively cheap, and important source of forage on many dairy farms in the Natal Midlands. Therefore improving animal performance on kikuyu will be of considerable economic benefit to the local dairy industry.

Growth patterns differ between breeds of cattle, both at the tissue level and in terms of growth of the whole. The most substantial cause of these differences in growth patterns is due to different breeds having differing mature masses, and, hence, being of different maturity types. Breed comparisons made between relatively early-, and relatively late-maturing breed types must, therefore, take into account the differing stages of maturity reached by the breeds in question, at a specific point in time. There is evidence that breed by nutrition interactions exist. This could imply that, on a given diet, such as kikuyu herbage, one breed may be able to utilise the diet with greater efficiency than another. Caution, however, must be exercised, as cattle at different stages of maturity will be depositing differing levels of muscle relative to fat, and, hence, efficiency, in terms of liveweight gains, may be deceptively different.

## 1.4 Objectives of the Current Study

1. To determine whether the growth pattern of Hereford and Holstein heifers is different on kikuyu pasture when no supplementation is offered.

2. If growth patterns differ between breeds, then to determine whether this is a result of dry matter digestibility differences or whether these differences exist due to differences in dry matter intake.

3. To determine the influence of the addition of concentrate to the diets of heifers grazing kikuyu, and to ascertain how this response differs between the two breeds used.

4. To test the use of n-alkanes as indigestible markers to determine differences in intake and digestibility between breeds of cattle on a tropical pasture.

# CHAPTER 2

# THE GROWTH OF HOLSTEIN AND HEREFORD HEIFERS ON KIKUYU (*Pennisetum clandestinum*) PASTURE

## 2.1 Introduction

A trial was designed to test if differences exist in growth rates between heifers of two breeds of cattle grazing *ad lib.* kikuyu pasture, with and without supplementation with concentrate feed. The intake of kikuyu was measured using alkanes as internal markers and is described in Chapter 3. Concentrate intake was monitored using a mobile feed wagon (MFW). Breed differences in height, mass and condition gain over the duration of the trial were also determined.

## 2.2 Materials and Methods

The trial was conducted at Cedara Agricultural Development Institute ($29^0 32^1$S; $30^0 17^1$E), situated in bioclimatic group 3 (Natal mistbelt) (Phillips, 1973) with an elevation of between 1076 m above sea level.

### 2.2.1 Treatments and experimental design

The trial was run over a twenty week period between 9 Nov. 1994 and 30 March 1995. Sixteen heifers were used, eight of Holstein-Friesian type and the remaining eight Herefords. For the first ten weeks, all the animals in the trial grazed kikuyu pasture on an *ad lib.* basis with no supplementation except for a mineral lick. Over this period (grass only), the two breed groups formed the two treatments. During the second ten week period (concentrate), all of the Holsteins and four of the Herefords were fed a restricted amount of concentrate feed on a daily basis in addition to kikuyu grazing on an *ad lib.* basis. The remaining four Herefords continued to graze kikuyu pasture on an *ad lib.* basis without supplementation. Thus, during the second phase of the trial, there were three treatments, one consisting of eight animals and the remaining two of four animals each. The first three weeks of the second phase of the trial were regarded as an adaptation period, as animals in the treatments receiving concentrate had to adapt to feeding from the MFW. The adaptation period was also necessary to prevent conditions of declining pH in the rumen.

### 2.2.2 Animals

#### *2.2.2.1 Selection of trial animals*

All animals were obtained from Cedara Agricultural Development Institute. Selection of animals on the basis of similar age rather than similar mass, both within and between breeds, was attempted. This was, however, influenced by the availability of animals at the start of the trial. The mean mass and age of the Herefords at the start of the trial were 229 kg (± 13.53) and 437.13 days (± 6.06), respectively. The mean mass, and age of the Holsteins were 284.5 kg (± 5.13) and 393.75 days (± 1.92), respectively. The ages, masses, and sires of all animals at the start of the trial are shown in Appendix 1.

#### *2.2.2.2 Management of the animals prior to the trial*

During the month prior to the trial, all of Herefords were fed *ad lib.* silage and hay. The Holsteins were also fed *ad lib.* silage and hay but additionally received 1.7 kg of supplement/animal/day. The supplement was of identical composition to that used in the current trial (table 2.1). Both Herefords and Holsteins were regularly dipped against external parasites, and dosed against internal parasites prior to the trial and received all necessary vaccinations timeously.

### *2.2.2.3 Weekly measurements*

Animals weights, condition scores and heights were measured weekly. These measurements were consistently taken at 8h00 to minimize effects of gut-fill on mass and to reduce disturbance to grazing behaviour. Height was measured using a measuring stick (Plate 1). This apparatus allowed a crossbar to slide with minimal resistance along the main vertical shaft to which a steel ruler was attached. When measuring height the cross shaft was allowed to drop onto the highest point on the animal's shoulder. A reading was taken where the lower side of the crossbar crossed the steel ruler. Care was taken to ensure that the base of the vertical shaft was touching the ground at a position level with the ground at the animal's feet at all times. It should be noted that accurate height measurement was difficult to obtain due to animal movement within the crush. Condition score assessments were usually taken by two people due to the subjective nature of this assessment. The condition scoring system proposed for dairy cattle by Mulvaney (1977) was employed.

### *2.2.2.3 Animal health*

All animals were orally dosed against internal parasites three times during the trial (9 November 1994, 2 February 1995, and 8 March 1995). Multispec (Janssen; active ingriedient: Mebendazole) was used as the remedy for all dosings. Dipping against external parasites was also performed three times over the trial period (8 November 1994, 22 December 1994, and 1 February 1995). The agent used was changed with each dipping to prevent a build-up of resistance. Products used for dipping were, in sequential order : Curatik (Shell Chemicals; active ingredient: Cypermethrin), Pouracide (Smith Kline Beecham; active ingredients: Alphamethrin, Cypermethrin, Tetrachlorinphos and Piperonylbutoxide) and Triatix (Hoechst; active ingredient: Amitraz). Curatik and Triatix were administered using a spray race, whilst Pouracide was applied as a pour on type agent with 5ml being applied to the head region, and 5ml around the tailhead. A subcutaneous vaccination against Quarter-evil (*Clostridium chauvoei*) was administered to all of the trial animals on 5 January 1995.

Four of the Holsteins contracted redwater (*Babesia bigemena*) during the course of the trial. Fortunately, this was quickly diagnosed and immediate intramuscular injections of Berinil and an oxytetracycline led to a quick recovery. None of the Herefords suffered from redwater.

#### *2.2.2.4 Mineral supplementation*

A mineral mixture was made available to the animals in sufficient quantity throughout the trial to allow an intake of 20 g/head/day. The mineral mix contained equal parts of iodized salt, dicalcium phosphate, feedlime and a commercial molasses meal.

### 2.2.3 Pastures

#### *2.2.3.1 Pasture rotation system*

A pasture rotation system was used to provide sufficient high quality kikuyu at all times so that animal intake was never restricted. Prevailing dry climatic conditions, however, made this a difficult objective to achieve. All treatment groups grazed in the same camps simultaneously throughout the trial. Initially four 0.5 ha camps were used for the trial, giving a stocking rate of 8 animals/ha. Later, it was, necessary, however, to incorporate two further 0.5 ha camps, due to a shortage of available dry matter caused by dry conditions. This effectively reduced the stocking rate to 5.3 animals/ha. Based on a subjective visual observation of the pasture, animals were moved to a new camp as soon as the forage on offer appeared to be limiting. That is, when the mean herbage height in the pasture appeared to be below approximately 10 cm. Animals spent 3 and 7 days in each camp, depending on the availability of good quality herbage.

#### *2.2.3.2 Fertilization practices*

The kikuyu pastures grazed during the trial were fertilized with 250 kg N/ha/annum, given as five 50 kg topdressings between September and April. The first topdressing was given as sulphur ammonium nitrate (SAN) to correct sulphur deficiencies, whilst the remaining topdressings were given in the form limestone ammonium nitrate (LAN). Phosphorus, and potassium are only applied according to soil analysis. The application of either of these two elements has not been necessary for several years.

#### *2.2.3.3 Rainfall*

Total rainfall from one month prior to, until the end of the trial showed a deficit of 37.44% relative to the mean over 80 years (ending 1995) recorded at the Cedara meteorological station. Monthly rainfall figures were lower than the mean for 80 years in all months, except December and March (Figure 2.1). The season was unusually dry with reasonable rainfalls falling late, and, therefore, being of limited benefit during the trial. Mean monthly temperature during the trial was higher than the 80-year mean except in October (Figure 2.1). It would, therefore, seem unlikely that a deficiency of heat units limited pasture growth.

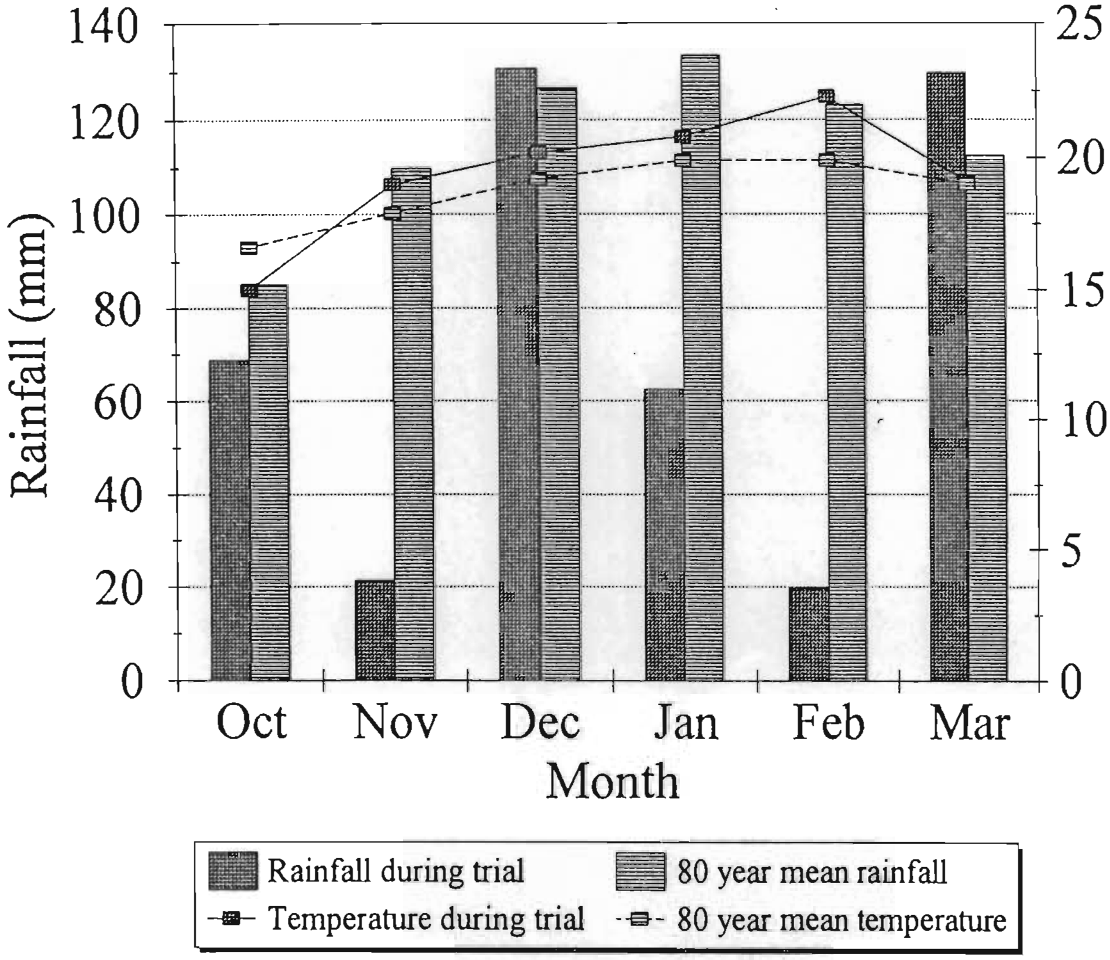

**Figure 2.1.** Total monthly rainfall (mm), and mean monthly temperature (°C) from one month prior to, until the end of the trial period shown relative to the 80 year means (Cedara meteorological station, Cedara Agricultural Development Institute).

### *2.2.3.4 The use of the pasture disc-meter*

The pasture disc-meter was used in this trial primarily to estimate the herbage DM available to animals before they entered camps ("IN" readings) and to observe how this changed over the season. The disc-meter was also used periodically to measure available herbage DM when animals were removed from the camps ("OUT" readings). The differences between "IN" and "OUT" readings was used to obtain a rough estimate of the herbage collectively consumed by the animals during their period of stay in a specific camp.

It was necessary to calibrate the disc meter in order to relate sward height to the mass of available herbage DM. This correlation will clearly vary depending on the density at different levels of the grass sward. This, in turn, relates to factors such as previous management and prevailing environmental conditions. It was, therefore advised that the disc-meter be calibrated for each camp on an individual basis (Hardy, 1994). The disc meter was calibrated by regressing the dry weight of grass falling under the disc meter against the sward height reading obtained from the disc meter at 50 different points for each camp. Bransby and Tainton (1977) claimed that there was little statistical advantage in using more than 50 calibration points. Calibration points were chosen so that a fairly large range in sward heights about the mean was measured. This gave a more reliable final regression for a wide range of sward heights.

The mass of herbage falling under the disc meter was estimated by placing a sampling cylinder around the circumference of the disc-meter (Figure 2.2). The disc meter was removed and the herbage within the perimeter of the cylinder was cut using sheep-shears to a level of approximately 1 cm. Herbage below this level was assumed to be unavailable to the animal. The cut herbage was then placed inside a brown paper packet of known mass and placed in an oven at $70^0$ C for 48 hours. The weight of herbage DM falling under the disc meter was determined from the dried sample. An indication of the precision of the calibration regression lines was obtained by using $r^2$ values (Mckenzie, 1994).

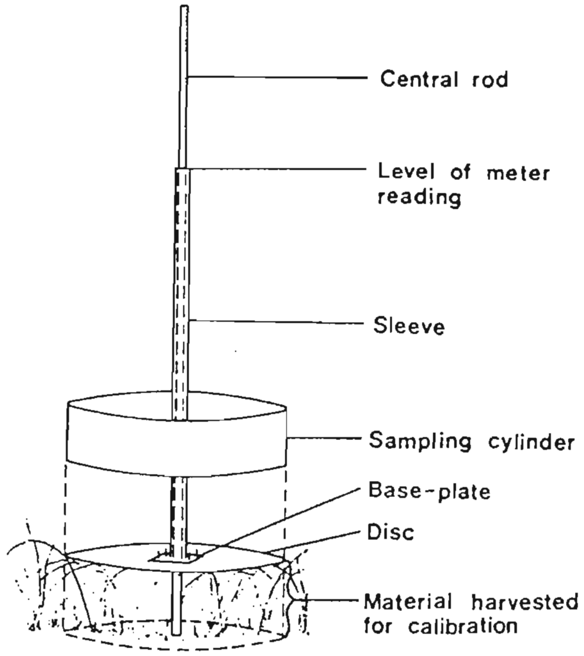

**Figure 2.2**. The pasture disc meter and sampling cylinder (after Bransby and Tainton, 1977).

Routine "IN" and "OUT" readings were taken by recording the sward height at 100 randomly chosen points throughout the camp. The mean sward height was related to the mean herbage mass per disc-meter area using the established regression for a specific camp. The total mass of available herbage DM could then be calculated by multiplying the obtained value by the area of the camp divided by the area of the disc meter.

#### *2.2.3.5 Pasture quality assessment*

Herbage samples were taken weekly throughout the trial. ("Grab" samples taken by studying the animals' grazing behaviour and attempting to hand-pluck as representative a sample of the herbage consumed by the animals as possible.) Samples were analysed at the Department of Animal and Poultry Science, University of Natal for protein, calcium, phosphorus, fat, ash, moisture, NDF and ADF.

### 2.2.4 Concentrate feeding

The MFW (Plate 2) was built and first used by Bruce Allwood over the 1993/94 summer season at Baynesfield Estates. A more detailed technical description of the MFW is provided by Allwood, 1994.

#### *2.2.4.1 The cattle code system*

The cattle code system provided by Milkrite, Heilbron, South Africa is a computerised cattle feeding system that allows animals to be fed concentrates on an individual basis. The principle behind individual feeding lies in the recognition of individual animals by means of a code on a transponder attached to the neck collar of each animal (Plate 3). At the front of each feed bin, a transmitter-receiver (interrogator) is positioned so that the transponder on the collar of any animal feeding from the bin will come into close contact with it. On receiving the individual code emitted by the transponder, the interrogator relays information to the central computer which then takes some form of action, such as dispensing feed. If the computer dictates that feed is to be dispensed then power is relayed to an auger motor. The auger motor turns the feed auger connected to it through one complete revolution, causing one feed portion to be dispensed into the feed trough directly below it (Figure 2.3).

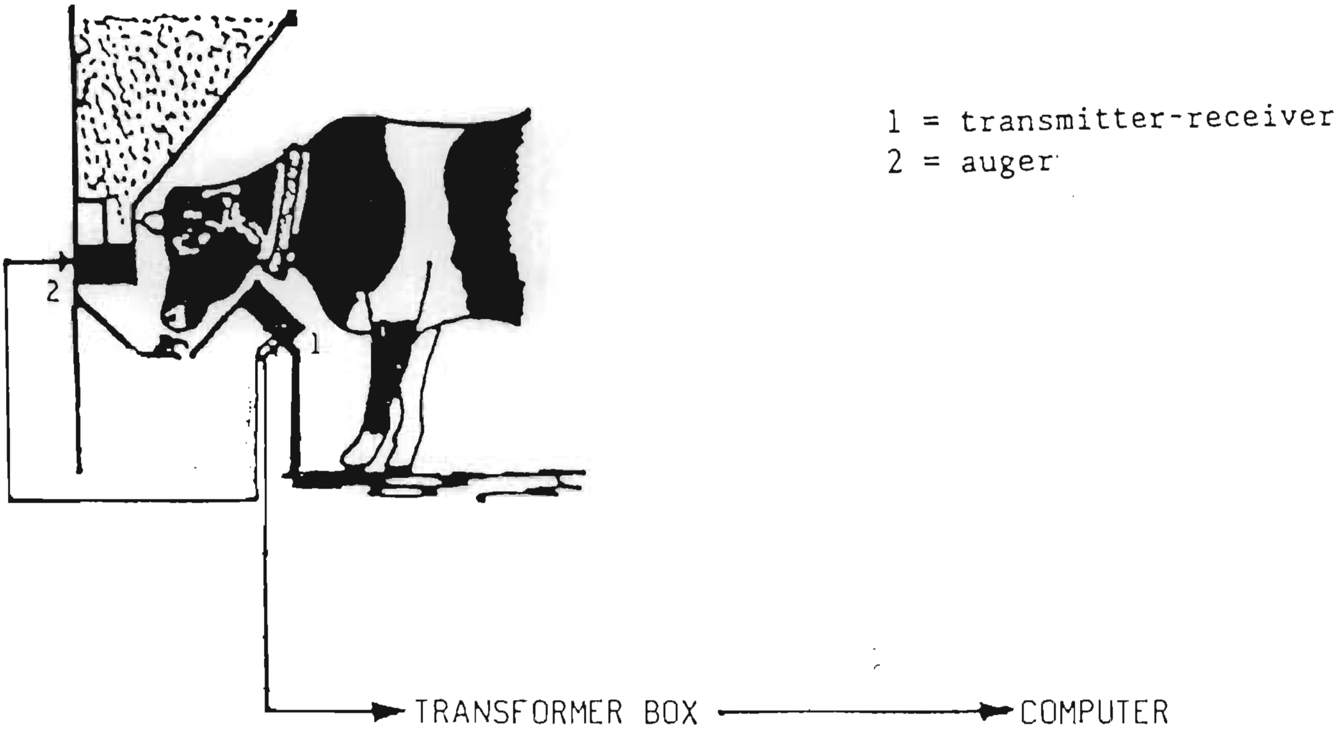

**Figure 2.3.** Diagrammatic representation of the cattle code system.

The amount of feed dispensed per auger revolution is dependent on the nature of the feed inside the feed bins and calibration was, therefore, necessary. This was done for each of the eight feed augers individually, as it was found that there was variation in the amount of feed dispensed per auger revolution between augers. This was possibly due to the fact that some of the augers may have turned through slightly less than $360^0$ per revolution owing to mechanical friction. Calibration was done by manually programming the computer to turn the relevant auger through one revolution, catching the dispensed feed in a pre-weighed packet and then weighing the feed portion. This process was repeated several times for each auger. The mean feed portion weight was then programmed into the computer. The calibration procedure was carried out a number of times during the trial to ensure that mechanical variation was accounted for.

The cattle code computer allows a daily feed allowance for each animal to be set. It is also possible to break down the daily 24-hour period into shorter sub-cycles. Therefore, the animal will only be permitted to eat a portion of its total daily concentrate ration at any one time, and will have to wait until a later period for the remainder. This is obviously beneficial where animals are fed large amounts of concentrates, potentially leading to acidosis and other rumen complications.

A time is programmed as the start of the feed cycle. Each day at the specified time, the new feed cycle begins and the animals' daily feed allowances are reset to their programmed values. Daily feed consumption for all animals can be read from the computer just prior to the onset of the new feed cycle. With the onset of each new feed cycle, daily consumption values are reset to zero and are added to a running total called "concentrates since calving".

The MFW has four feed troughs, each being connected to two feed bins. It is not possible to differentiate between the four feeding points when programming the computer and, therefore, no more than two feed types can be fed through the system at any one time. For the purpose of the current trial, however, only one feed type was used. The same feed was placed in all of the eight feed bins and the computer was programmed to feed a portion of each animal's daily allowance from the inner feed bins, and the remainder from the outer feed bins. The computer treated these as two separate feeds, but this was easily overcome by summing the daily intakes from inner and outer feed bins for each animal. A further consequence of the inability to differentiate between feed points is that animals with transponders can feed equally from any of the four feed points. It is not possible to differentially regulate certain animals to feed from specific feed points.

### *2.2.4.2 Using the cattle code system in a mobile form*

The most unique feature of the MFW is its mobile nature, allowing it to be easily towed behind a tractor and moved from one camp to the next, following the rotational grazing pattern of the cattle. Two feed points are located on either side of the MFW, each with a set of gates allowing only one animal to feed from a specific feed point at any one time. The ability of two or more animals to feed from one feed point at the same time would clearly cause incorrect feed allocation, and hence inaccurate data collection.

The central computer unit, feed bins, and batteries are located inside the MFW. The cattle code system is powered by a 24 volt DC supply. The MFW supplies this current through the use of two heavy duty 12 volt batteries connected in series. A pair of solar panels located on the roof of the MFW help to recharge the batteries during the day. At night the MFW runs solely off the batteries. Unfortunately, the solar panels that were fitted did not provide sufficient energy for the system to be self-sustaining. A second pair of batteries, charged using a battery charger, was, thus, required to alternate with the first pair. The frequency with which batteries need to be alternated was dependent largely on the amount of daily cloud cover.

### *2.2.4.3 Use of the mobile feed wagon in the trial*

The Herefords were split into two treatments on the basis of equivalent mass. To achieve this, the eight animals were listed in descending order of mass and alternately allocated to the first and second treatments. Treatment 1 did not receive concentrates and were not given transponders. Treatment 2 and all the Holsteins were given transponders. During the three week adaptation period, intake readings from the MFW were closely followed to monitor the animals' progress in learning to feed from the MFW. During the adaptation period it was observed that some of the Herefords were bullying other animals at the MFW. The 'bully' waited until feed had been dispensed into the feed trough for another animal, and then rammed the animal from behind causing the feeding animal to panic and retreat whilst the aggressor slipped between the two gates to takes its place and the previous animal's feed (Plate 4). This problem was alleviated to some extent by swopping two of the Herefords between the treatment recieving concentrate and the control treatment. There were also two Holsteins that ate very little from the MFW during the adaptation period. Unfortunately there was little that could be done about this problem beyond leaving concentrate in the troughs as regularly as possible during the adaptation period in an attempt to attract them.

The cattle code system was programmed to feed each of the animals receiving concentrate 1.7 kg of feed per day. This daily allowance and the feed type were based on allowances given to Holstein heifers of equivalent age on kikuyu within the Cedara dairy herd. The supplement given comprised 78% maize meal, 20% high protein concentrate (HPC), and 2% premix. The premix contained salt, molasses meal, feedlime, magnesium oxide, and dicalcium phosphate. Results of a laboratory analysis of the supplement are shown in Table 2.1.

**Table 2.1.** Composition of the concentrate fed (results on an as-fed basis)

| Protein (%) | Calcium (%) | Phosphorus (%) | Fat (%) | Ash (%) | ME (MJ/kg) |
|---|---|---|---|---|---|
| 12.40 | 0.79 | 0.50 | 3.96 | 3.38 | 11.34[1] |

[1] Derived using ME of HPC and maize meal as 9.8 and 12.02 MJ/kg respectively (Bredon *et al.*, 1987).

The daily feed cycle was set to start at 9:00h each morning. Four six-hour sub-cycles were set up within the main 24-hour feed cycle. Animals were allowed to access one quarter of their daily allocation in the first sub-cycle and the balance from the second cycle onwards (i.e. from 15:00h).

The cattle code feeding system was disabled due to power supply related problems over two periods during the duration of its use. These periods were 2 and 7 days in length. Concentrate was fed manually to allow an average intake of 1.7 kg/animal/day during these periods. Half of the total daily feed allocation was collectively offered in the morning and the remaining portion in the late afternoon. The control treatment was separated during feeding to prevent them access to the concentrate. Individual feeding was, unfortunately, impossible over these periods due to the labour and time that would have been required. Daily intakes were estimated assuming equivalence of intake between animals and were not based on previously recorded intake values as it was felt that individual feed intake may have been different when animals were fed in the trough compared to at the MFW.

### 2.2.5 Statistical analysis

Quattro Pro V (Borland International) was used to perform multiple regression analyses to calibrate the disc meter and to identify possible trends in the chemical fractions of kikuyu over the season. Multiple regression analyses of a more complex nature, requiring comparisons between treatments, were performed using Genstat (1987). Differences between treatment means and regression coefficients were tested for significance using the Students t-test at the 1, and 5% levels.

**Plate 1.** Measurement of animal height.

**Plate 2.** The mobile feed wagon (MFW).

Plate 3. Experimental animal displaying attached neck collar with transponder.

Plate 4. Bullying at the MFW

## 2.3 Results

### 2.3.1 Herbage availability : quantity, and quality selected

### *2.3.1.1 The mass of available herbage*

Calibration data pertaining to the linear regressions relating sward height to herbage mass are given in Appendix 2A. The established regressions for each of the six camps gave $r^2$ values ranging between 0.54 and 0.70 for camps Y10 and X52, respectively (Appendix 2B).

Total available herbage on offer (kg DM) on entry to each new camp throughout the duration of the trial varied considerably between camps (Table 2.2). The highest and lowest mean pasture yields at the time of animal entry into the camps were 2198 kg DM (±71.50) and 789.41 (±73.83) for camps Y10 and X52, respectively. Pasture yields appeared to drop initially, but recovered and increased later in the trial. It is thought that this response was largely related to heavy rains late in December, after a long dry period. Available herbage yield was lowest during early- to mid-December, resulting in a corresponding decline in heifer liveweight gains over this period. Disc meter measurements of pasture height from which pasture DM yields are derived are presented in Appendix 3A.

The mean daily herbage intake (DM) collectively estimated using the disc meter was 4.50 (±1.01) kg/head/day (Appendix 3B). Intake tended to increase with increasing levels of available herbage on entry into the camps, suggesting that intake may have been periodically restricted due to low yields of forage in certain of camps. This occurred despite attempts to move animals timeously when visual appraisal of the camps suggested that herbage was limiting. The concept of periodic restriction is supported by the fact that estimates of available herbage on leaving camps were sometimes higher than estimates when entering different camps. It would seem that some camps were inherently higher producing than others over the trial period.

**Table 2.2.** Total available herbage on offer (kg DM) on entry into each new camp.

| | Camp | | | | | |
|---|---|---|---|---|---|---|
| Date | BSS | BSN | X 51 | X 52 | V 10 | Y 10 |
| Nov. 1 | 1629.12 | | | | | |
| 24 | | | 1237.89 | | | |
| 1 | | | | 756.99 | | |
| 8 | 1358.88 | | | | | |
| Dec. 15 | | 1383.06 | | | | |
| 22 | | | 942.39 | | | |
| 29 | | | | 548.15 | | |
| 5 | 1870.92 | | | | | |
| Jan. 12 | | 1475.51 | | | | |
| 19 | | | | | | 2502.66 |
| 26 | | | | | 1652.23 | |
| 2 | | | 1736.69 | | | |
| 6 | | | | 1063.09 | | |
| Feb. 9 | 2927.71 | | | | | |
| 16 | | 1637.66 | | | | |
| 23 | | | | | | 1894.55 |
| 28 | | | | | 1846.65 | |
| 10 | | | 1396.8 | | | |
| Mar. 22 | 2010.31 | | | | | |
| 25 | | 2114.14 | | | | |
| Mean | 1959.39 | 1652.59 | 1328.44 | 789.41 | 1749.44 | 2198.61 |
| S.E.[2] | 68.12 | 76.77 | 37.53 | 73.83 | 77.69 | 71.50 |

[1] camps were grazed simultaneously.

[2] derivation of S.E. values given in Appendix 3C.

In addition to having the lowest mean DM yield on animal entry into the camps, X52 also realised the lowest levels of intake by animals grazing it. Intake estimates were in fact negative for two grazing periods on X52 (Appendix 3B). This higher mean disc height when animals left the camp compared to when they arrived could be a consequence of pasture growth exceeding the rate at which it was cropped by the animals or, alternatively, a low level of accuracy in the estimation of sward height, possibly as a result of a relatively high slope gradient. The high $r^2$ value of the calibration regression for X52 relative to the other camps suggests that the first explanation is more likely.

#### *2.3.1.2 Herbage quality*

The mean concentrations of the different chemical components in the herbage selected over the trial period based on weekly sampling are shown in Table 2.3. Weekly sampling results on which these means are based are shown in Appendix 4A. Regression of the concentrations of the different fractions of kikuyu against time over the duration of the trial period showed a decrease in DM%, ash and protein as time progressed. However, none of these trends were significant ($P > 0.05$) (Appendix 4B).

**Table 2.3.** Mean values for the different chemical fractions of the herbage grazed based on weekly sampling (expressed on a DM basis).

| Fraction | DM (%) | Protein (%) | NDF (%) | ADF (%) | Ash (%) | Ca (%) | P (%) | Fat (%) |
|---|---|---|---|---|---|---|---|---|
| Mean | 23.83 | 18.32 | 55.70 | 27.71 | 8.43 | 0.48 | 0.24 | 2.47 |
| S.E. | 0.83 | 0.47 | 0.74 | 0.42 | 0.19 | 0.02 | 0.01 | 0.09 |

### 2.3.2 Animal growth, and condition score changes over the trial period

#### *2.3.2.1 Growth in mass*

Animal weights were recorded weekly (Appendices 5A, and 5B). The mean mass gain of all animals in the trial increased in the week subsequent to dosing (Figure 2.4) compared to the previous week at each of the three dosing dates.

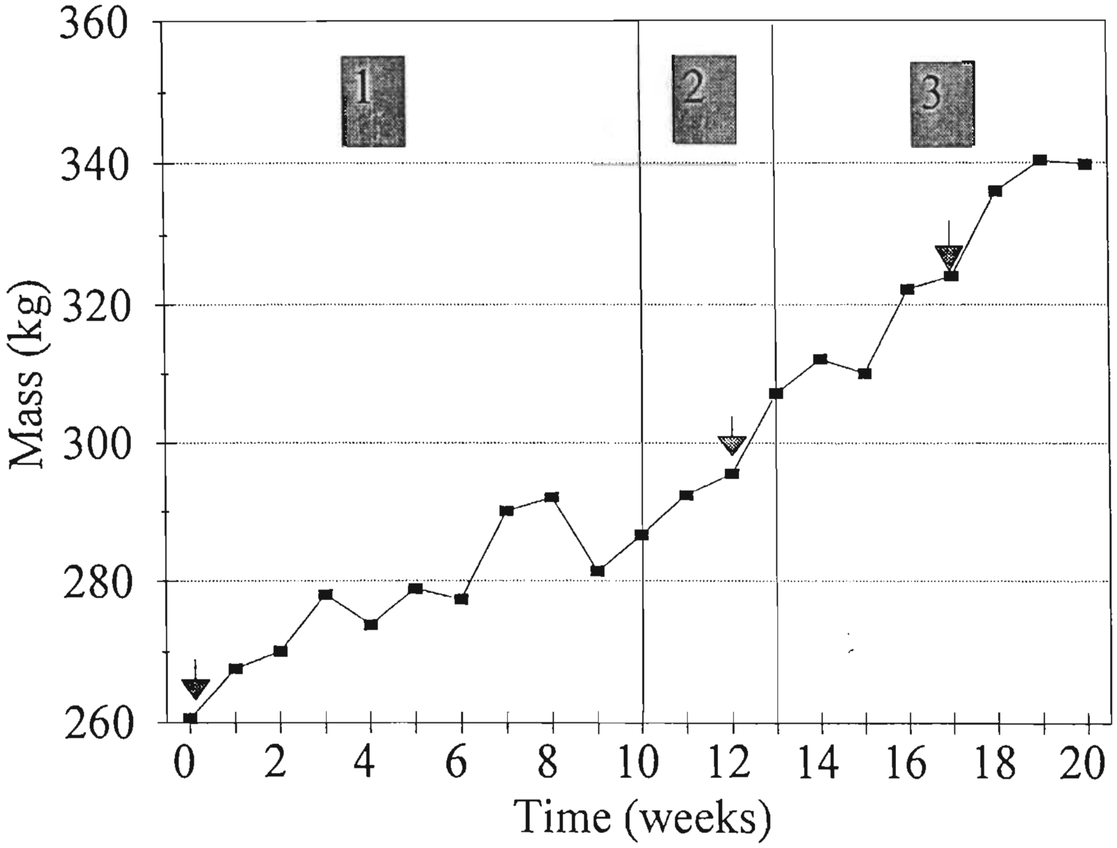

**Figure 2.4.** The correlation between the mean mass of all treatments and time over the different periods of the trial (where 1 = grass only period, 2 = adaptation period, and 3 = concentrate period) (arrows indicate dosing dates).

During the initial (grass only) period, the Herefords entered the trial at a lighter mass ($P < 0.01$) and grew at a faster rate in terms of ADG ($P < 0.01$) than the Holstein treatment (Table 2.4, Figure 2.5, and Appendix 5C). The Holstein treatment, in fact, grew at a rate not significantly greater than zero over this period ($P > 0.05$). No significant differences in rate of mass gain ($P > 0.05$) were found during the grass only period of the trial between the two Hereford treatments, suggesting unbiased treatment selection at the end of this period. The model for predicting weight produced by Genstat (1987) over the grass only period of the trial had an adjusted $r^2$ value of 25.7%. Reliability of the model remained low, but increased to 52.4% when one Hereford (36) was removed from the model. It is thought that the large impact of this animal on the model was due to its high initial mass relative to the other animals in its treatment (Appendix 5C).

**Table 2.4.** Average daily gains of the three treatments over the two periods of the trial.

| | Average Daily Gain (kg/day) | | | |
|---|---|---|---|---|
| Treatment | Grass only period | S.E.M. | Grass + Concentrate period | S.E.M. |
| Hereford (C)[1 3] | 0.84 | 0.13 | 0.78 | 0.03 |
| Hereford (WC)[2 3] | 0.79 | 0.05 | 0.82 | 0.08 |
| Holstein | 0.04 | 0.04 | 0.53 | 0.10 |

[1] Hereford (C) = Herefords receiving concentrates

[2] Hereford (WC) = Herefords not receiving concentrates

[3] Hereford (C), and (WC) formed the same treatment during the grass only period.

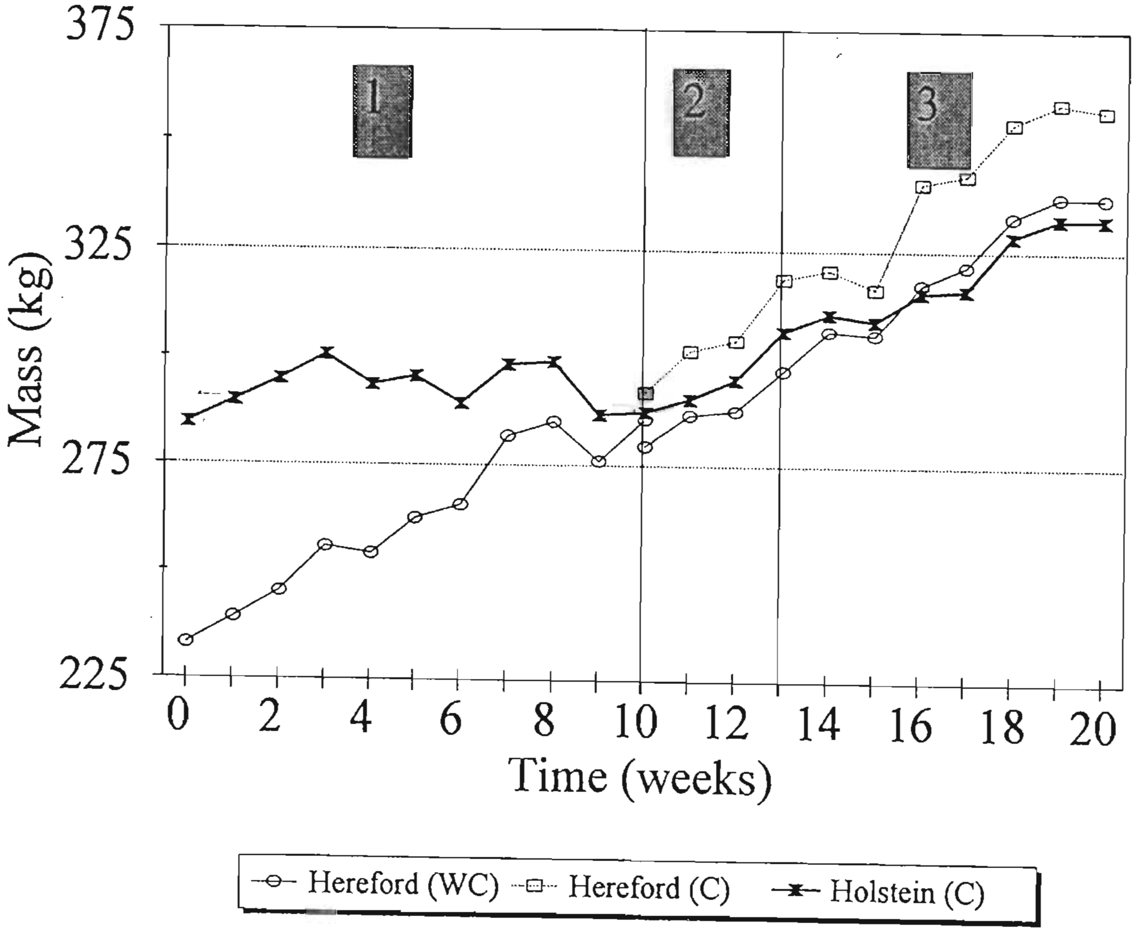

**Figure 2.5**. The correlation between mass and time for the separate treatments over the different periods of the trial (where, 1 = grass only period, 2 = adaptation period, and 3 = concentrate period) (C = treatment recieving concentrate, and WC = treatment not receiving concentrate).

During the second (concentrate) phase of the trial, all three treatments had similar initial mass and ADG's which were not significantly different ($P > 0.05$) (Figure 2.5, and Appendix 5C). The ADG's of both the Hereford treatments were no different from that of the original Hereford treatment over the grass only period, from which they both originated. The Holsteins, however, gained mass at a faster rate ($P < 0.05$) over the concentrate period than the grass only period. The proposed model for predicting mass based on breed and weeks from the start of the trial had an adjusted $r^2$ value of 13.5%. Removal of one Holstein (20) increased the reliability of the model to 20.1% (Appendix 5C). It is suspected that this effect was due to the high initial mass of the animal concerned compared to others within the treatment.

Despite the relatively low reliability of the linear models, the lack of significance of deviations from linear regression ($P > 0.05$) indicated that linear regression was the best way of describing these data (Appendix 5C).

### *2.3.2.2 Growth in height*

The measurement of animal height was performed weekly (Appendices 6A and 6B). The Holstein treatment had significantly greater initial height (cm) at the start of the trial ($P < 0.01$). No significant differences ($P > 0.05$) between treatments in terms of rate of increase of height were evident within either the first (grass only) or the second (concentrate) period of the trial. Gain in height over time was significant ($P < 0.01$) for both treatments over the first (grass only) period of the trial, but was not significant ($P > 0.05$) for any of the three treatments over the second (concentrate) phase of the trial (Figure 2.6 and Appendix 6C). Regression equations created using Genstat (1987) showed a higher reliability in predicting height than those generated for mass estimation. The $r^2$ values for models predicting height of the animals for the first, and second periods of the trial were 69.6%, and 62.4% respectively (Appendix 6C). Removal of Hereford no.36 from the analysis (on the basis of large initial size relative to other animals within its treatment) over the grass only period led to no improvement in the reliability of the model predicting height. Reliability was however increased to 69.6% when Holstein no.20 was dropped from the model over the concentrate period.

A model fitted to compare height growth over the entire duration of the trial showed that differences in rate of height gain were not significant (P > 0.05) between the two breeds. However when Holstein no. 20 was dropped from the analysis, the Herefords had a significantly higher rate of height gain than the Holsteins (P < 0.05) (Appendix 6C).

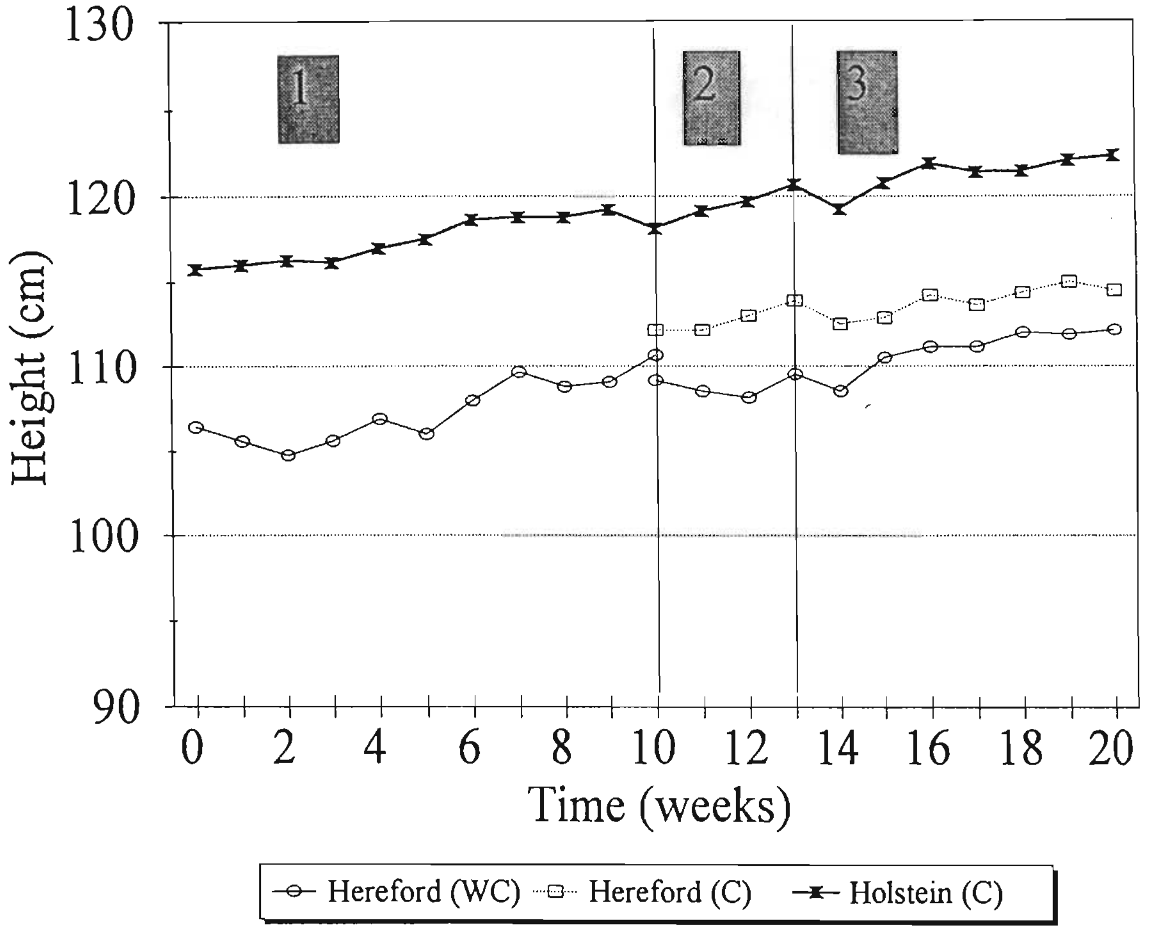

**Figure 2.6.** Weekly heights of the different treatments over the trial period (where 1 = grass only period, 2 = adaptation period, and 3 = concentrate period) (C = treatment receiving concentrate and WC = treatment not receiving concentrate).

*2.3.2.3 Changes in condition score*

Animals' condition scores were recorded weekly (Appendices 7A and 7B). At the start of the trial, condition score was not significantly different (P > 0.05) between the Hereford and Holstein treatments. Over the first (grass only) period of the trial, the Herefords gained 0.07 condition score units per week (P < 0.01), whilst the Holsteins lost condition at an equivalent weekly rate (P < 0.01). The net result of these changes in condition over time was that the Herefords finished the first trial period in better condition than their Holsteins counterparts ($P < 0.05$) (Figure 2.7 and Appendix 7C).

At the start of the second (concentrate) period of the trial both of the Hereford treatments were higher in mean condition score than the Holstein treatment ($P < 0.01$). There was, however, no evidence of significant differences ($P > 0.05$) in initial condition score between the two Hereford treatments. Both Hereford treatments gained condition score at a significant rate over this period ($P < 0.01$). Although the Hereford control treatment gained in condition at a greater rate than the Hereford treatment recieving concentrates (0.05 vs. 0.03 condition score units per week), this difference was not significant ($P > 0.05$). The Holstein treatment showed neither a significant gain, nor a loss in body condition over this period ($P > 0.05$) (Figure 2.8 and Appendix 7C).

Models predicting condition score had high reliability values (69.9 and 96.5% for the first and second periods, respectively), especially over the second period (Appendix 7C).

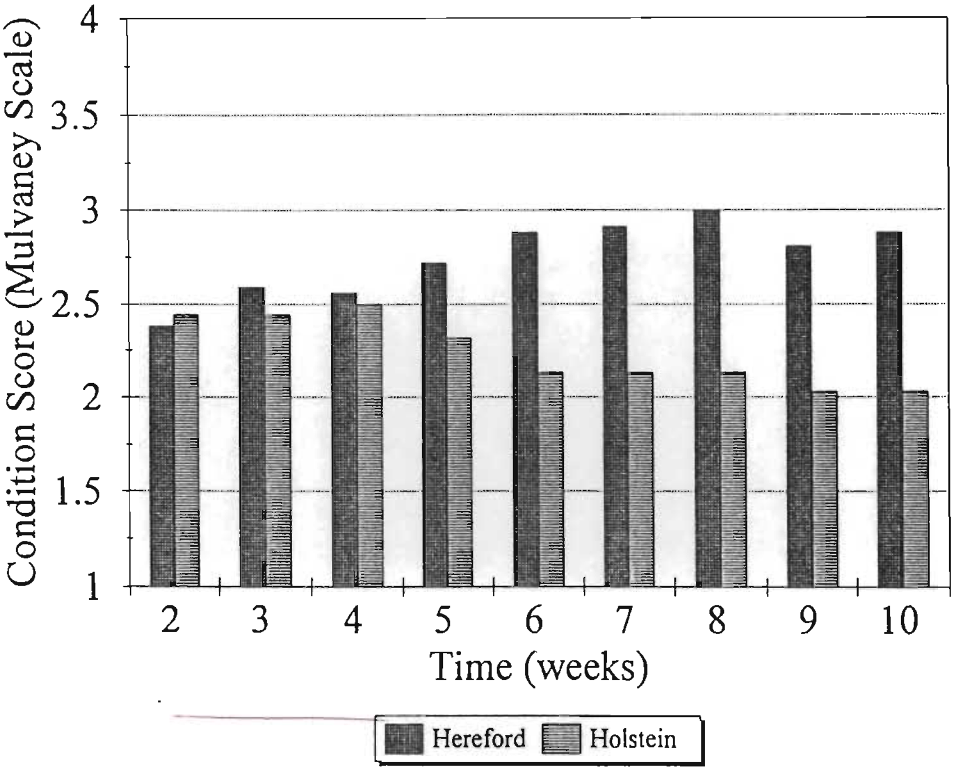

**Figure 2.7.** Weekly condition scores of the two treatments over the first period of the trial where *ad lib.* kikuyu forage was fed without concentrates to both treatments.

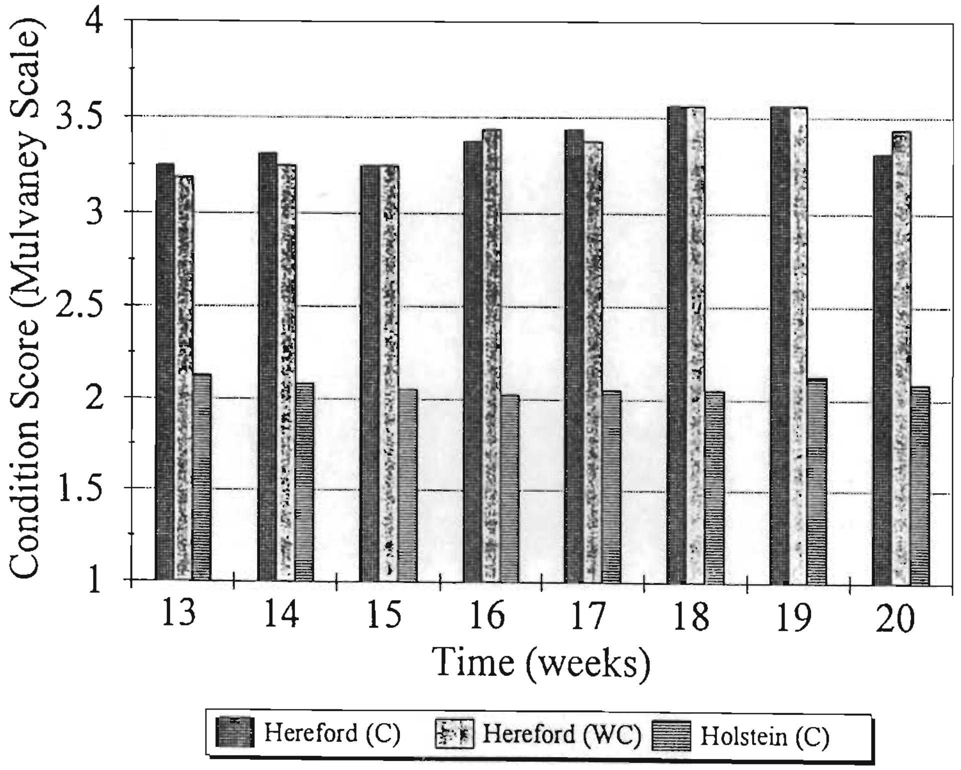

**Figure 2.8.** Weekly condition scores of the three treatments over the second period of the trial where *ad lib.* kikuyu forage was fed together with limited concentrate depending on treatment (where, C = treatment receiving concentrate and WC = treatment not receiving concentrate).

### 2.3.3 Concentrate intake

Mean individual concentrate intakes are shown in Table 2.5 (derived from Appendix 8A). Although daily concentrate intake (kg/day) was higher for the Herefords than the Holsteins, this difference was not significant ($P > 0.05$). When concentrate intake was expressed per unit metabolic mass there was still no significant difference ($P > 0.05$) in intake level between treatments (Appendix 8B). Regression of ADG (kg/day) against daily concentrate intake showed no significant trends ($P > 0.05$) in ADG with increasing levels of concentrate intake within either of the treatments. Regression of ADG against intake on metabolic mass scale gave a positive regression coefficient for the Holstein treatment and a negative coefficient for the Hereford treatment. Neither of these coefficients were, however, significant ($P > 0.05$) (Appendix 8C).

**Table 2.5.** Individual intake of concentrate (kg/day, and g/kg $LW^{0.75}$/day), and ADG (kg/day) for the two treatments offered concentrate over the second period of the trial.

| Treatment | Animal no. | Intake (kg/day) | Intake (g/kg $LW^{0.75}$/day) | % of total | ADG (kg/day) |
|---|---|---|---|---|---|
| Hereford | 8 | 1.64 | 24.43 | 96.52 | 0.73 |
| | 16 | 1.68 | 21.17 | 97.6 | 0.84 |
| | 33 | 1.38 | 18.13 | 81.27 | 0.73 |
| | 36 | 1.37 | 14.75 | 80.52 | 0.82 |
| | Mean | 1.51 | 19.19 | 88.98 | 0.78 |
| Holstein | 19 | 1.42 | 18.92 | 83.31 | 0.59 |
| | 20 | 1.69 | 19.59 | 99.16 | 0.94 |
| | 21 | 1.1 | 14.94 | 64.47 | 0.16 |
| | 22 | 1.15 | 15.87 | 67.71 | 0.92 |
| | 23 | 1.42 | 18.62 | 83.55 | 0.47 |
| | 24 | 1.41 | 20.14 | 82.83 | 0.12 |
| | 25 | 1.43 | 18.75 | 84.03 | 0.73 |
| | 27 | 0.31 | 4.09 | 18.01 | 0.42 |
| | Mean | 1.24 | 16.40 | 72.88 | 0.54 |

## 2.4 Discussion

### 2.4.1 Herbage availability and animal selection

Intake may have been periodically restricted as a result of low levels of herbage on offer. This was unfortunate as it may have resulted in differences in dry matter intake between breeds to a certain extent being a consequence of each breeds competitive ability rather than inherent physiological differences between breeds. Competition between animals will clearly increase as the effects of stocking rate increase. A further consequence of increased stocking pressure is likely to be a decline in pasture variability, potentially forcing animal selection to decline. Thus, animal selection for leaf over stem or vice versa may have been periodically lowered due to competitive pressures.

The mean CP concentration of 18.32 in the grazed herbage, was higher than the optimum value of 14% for which it is suggested cattle grazing kikuyu select (Dugmore *et al.*, 1991). This suggests that the animals may have been attempting to decrease the protein concentration of their diets by selecting for material with a lower crude protein content than the mean of the herbage on offer. This may in turn have led to increased selection for stem which has a lower CP content relative to the leaf fraction (Mears and Humphreys, 1974a). A reduction in the well documented high leaf to stem ratio in the diet selected by animals grazing tropical pastures would clearly be the result of such grazing behaviour. Crude fibre was not measured, but an attempt was made to use a regression equation which related ADF to CF for kikuyu (Dugmore *et al.*, 1986)[1]. The regression gave an extremely low estimate of CF (13.66%), far below the suggested optimum of 30% for which it is suggested cattle grazing kikuyu select (Dugmore *et al.* 1991). CF may have been underestimated as a result of either the recorded ADF estimates being beyond the reliable range of the regression equation used, or of biased sampling procedures. Pattinson (1981), however, found the mean ADF% from samples taken over 13 days from two oesophageally fistulated steers grazing kikuyu to be 29.11%; not greatly different from the value of 27.71%

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[1] CF estimated using the regression equation, $ADF = 20.06 + 0.56\ CF$ ; $r = 0.607$ ; $P < 0.001$ (Dugmore *et al.*, 1986)

obtained in the present trial. The animals in Pattinson's (1981) trial actively selected for higher levels of ADF than the mean on offer. It would thus appear probable that animals in the current trial were practising selective grazing with a view to increasing the fibre content of their diets. This in turn suggests that selection within the leaf fraction may have been towards older, more mature material with a higher fibre content. The mean calcium to phosphorus ratio of 2:1, suggests that this ratio was not a limiting factor in the herbage on offer.

### 2.4.2 Animal Growth (mass and height)

At the start of the trial, both breeds were at similar stages of maturity, with the estimated values for the Herefords and Holsteins being 0.47 and 0.49, respectively[2]. Higher condition scores of mature beef breed females when compared to dairy breeds could have led to an overestimation of mature mass for the Herefords. If this were valid, the stage of maturity of the Herefords would be increased, possibly leading to an even greater similarity in the stage of maturity between the two breeds. Similar maturity stage between the breeds implies deposition of bone, muscle and fat in similar ratios. This, in turn, suggests that efficiency of liveweight gain should have been similar. Alternatively, the dietary requirements of energy and protein for a given rate of growth should not have been greatly different between the breeds when expressed relative to current mass.

The lower performance of the Holsteins than the Herefords during the grass only period could be due either to a decreased efficiency of utilization of the ingested herbage (possibly pertaining to digestibility differences between breeds), or due to differences in DMI. Garrett (1971) showed that Herefords were 20% and 12% more efficient than Holsteins in converting feed energy consumed above maintenance to energy storage as fat and protein. It is, however, likely that these results may have reflected differences in the energetic efficiency of fat deposition relative to protein deposition, as the Herefords had a higher proportion of fat in their gains. Differences

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[2] Maturity stage was expressed using equation (10) in Chapter 1. The mature masses of both breeds were estimated from the mean masses of breeding females after second calving in their respective herd groups (500 and 580 kg for the Herefords and Holsteins, respectively).

in digestibility of the offered ration were shown to be non-significant between breeds in one trial undertaken by Garrett (1971). There is, in fact, limited experimental evidence of between breed differences in the overall digestibility of the diet. If these differences were significant in the current trial, it would seem unlikely that they would be of sufficient magnitude to cause the observed breed differences in performance.

The marked lack of response to concentrate supplementation in the case of the Herefords, compared to significantly increased ADG in the case of the Holsteins ($P < 0.05$) may be indicative of DM intake differences over the grass only period. The Herefords offered concentrate may have substituted concentrate for grass, whilst the Holsteins may have consumed concentrate in excess of the kikuyu they were originally grazing. Rumen size may have been the limitation forcing the Herefords to substitute grass for concentrate, whilst the hypothesised lower intake of the Holsteins allowed concentrate intake with limited impact on the level of grazed herbage. ARC (1980) requirements for ME intake to achieve the observed growth rates over the grass only period confirm this view. Required mean daily intakes of kikuyu for the Herefords and Holsteins over this period were estimated as 7.78 and 4.03 kg/day respectively where the ME content of kikuyu was taken as 9 MJ/kg (Dugmore, 1995). van Ryssen *et al.* (1976) claimed that improved performance observed in sheep grazing kikuyu was influenced by stocking rate, suggesting that as herbage becomes more limiting, so the response to additional energy supplementation will increase. As the intake of concentrate was similar between breeds when expressed per unit metabolic mass and the growth response attributable to concentrate was higher for the Holsteins than the Herefords, it would appear that the Holsteins had a lower herbage intake. A confounding factor, however, is that the two breed treatments were under identical stocking pressure. Possible differences in intake of grazed herbage must, therefore, have been due to breed differences in grazing behaviour which may, in turn, be the result of genetic differences in digestive phenomena. Smuts *et al.* (1995), after observing high repeatability estimates for retention time of digesta in or passage rate from the rumen, suggested that these were inherent characteristics of the animal which would respond to genetic selection. Years of selection for different production purposes may have unwittingly led to differences in digesta kinetic characteristics between beef and dairy breed animals.

The mean daily concentrate intake of the Holsteins during the concentrate period supplied 14.06 MJ ME/day. If this was consumed in addition to the grazed kikuyu with no substitution effect, and if the previously estimated intake for the Holsteins remained unchanged then, an estimated deficiency of only 7% of the required ME to grow at the achieved mean rate over the concentrate period would result (ARC, 1980). It is, however, probable that some substitution of grass for concentrate may have occurred. This, together with the existing slight deficiency in ME, suggests that intake of grazed kikuyu may have increased relative to the grass only period. The absence of a Holstein control treatment during the concentrate period is regrettable as this may have illustrated this point. This was not possible due to the poor condition of the Holsteins at the end of the grass only period. The lack of significance ($P > 0.05$) of the regression relating individual ADG for the Holsteins to concentrate intake (g/kg $LW^{0.75}$/day) is somewhat surprising and it is suspected that this is the result of a limited number of animals with intakes distributed over a narrow range.

Increased mean gains subsequent to dosing for internal parasites are interesting to note as a similar response was obtained by Allwood (1994). It is suspected that this response is due not only to the control of internal parasites, but also, in part, to increased voluntary intake caused by the remedy due to a diminished parasite burden (Allwood, 1994).

Growth in height demonstrated the relatively inflexible nature of bone growth. The significance of regressions relating height to time during the grass only period ($P < 0.01$), but not during the concentrate period ($P > 0.05$), may have been due to growth pressure being relieved from bone and transferred to the relatively later-maturing tissues such as muscle and fat, as the animals approached maturity. The tendency for the Herefords to have a greater rate of height growth relative to the Holsteins over the entire duration of the trial may be indicative of the severity of growth retardation experienced by the Holsteins. The advanced maturity stage of the Herefords compared to the Holsteins as the trial progressed should have favoured the growth of an early-maturing tissue, such as bone, preferentially in the Holsteins.

### 2.4.3 Condition score

Two points must be noted when using condition score as a measure of differences in carcass fat levels between the two breeds. Firstly, subcutaneous fat has higher growth impetus relative to intramuscular fat (Callow, 1948) and, secondly dairy breeds have been shown to have a lower ratio of subcutaneous fat to intramuscular fat compared to certain beef breeds, such as the Hereford (Callow, 1961). The result of these differing ratios suggests that animals of equal liveweight and condition score but different breed type may have differing total body fat levels. This was confirmed by Wright and Russel (1984) who showed, by directly determined body composition, that British Friesian cows were fatter at any given condition score than Hereford x Friesian cows. Hence, the observed similarity in condition score between the Herefords and Holsteins at the start of the trial may be indicative of a higher total fat content in the Holsteins. Condition score has been shown to have a negative correlation with liveweight (Russel and Wright, 1983). The most probable hypothesis for the negative effect of condition score on maintenance energy requirements has a basis in the high maintenance costs of protein relative to fat. It could, therefore, be postulated that the maintenance costs of the Holsteins may have been lower, when expressed relative to liveweight than the Herefords at the start of the grass only period.

High growth impetus of a tissue is associated with a relatively later-maturing characteristic and a low preference for the allocation of nutrients over periods of nutritional stress (Berg and Butterfield, 1976). Nutritional deprivation will, therefore, be likely to have a greater impact on subcutaneous fat depots than on intramuscular fat levels. It would, therefore, seem feasible that condition score response to short term changes in nutrition may have been higher for the Herefords due to their increased proportion of subcutaneous to intramuscular fat compared to the Holsteins. A similar effect was observed by Wright and Russel (1984) who demonstrated that one unit of condition score was associated with a change of 2242 MJ of body tissue energy in Hereford x Friesian cows compared to 3478 MJ in Friesian cows.

The decline in condition score but maintenance of fairly consistent mass for the Holstein treatment over the grass only period suggests catabolism of fat tissue to support the costs of maintenance and limited muscle, bone and possibly, intramuscular fat growth. It would seem likely, on the other hand, that the Hereford treatment had surplus energy available which was used for the metabolism and storage of subcutaneous fat.

Over the concentrate period, intake of grass and concentrate provided sufficient energy for limited growth in the Holsteins. It would seem that this energy was preferentially allocated to bone, muscle and, possibly, intramuscular fat deposition, resulting in no visible improvement in condition. The higher amount of body tissue energy per unit increase in condition score for the Holsteins compared to the Herefords may have accentuated this effect. If the concentrate period had been longer, condition scores for the Holstein treatment may have improved as a result of a shift in the preferential allocation of nutrients for tissue deposition towards the later-maturing tissues as the animals approached their mature mass. Theoretically, the Hereford treatments should have had a higher propensity to fatten during the concentrate period than the grass only period, due to this advanced stage of maturity. The absence of an increase in rate of condition score gain may have been due to lower energy intake resulting from reduced intake of grass as a result of intake control mechanisms. There is sufficient evidence to indicate that fatness reduces intake in cattle (McDonald *et al.*, 1988).

# CHAPTER 3

# THE USE OF N-ALKANES TO DETERMINE THE INTAKE AND DIGESTIBILITY OF KIKUYU (*Pennisetum clandestinum*) PASTURE BY CATTLE

## 3.1 Introduction

N-alkanes were used as indigestible markers to estimate differences in intake and digestibility between Hereford and Holstein heifers, grazing kikuyu with and without concentrate. The technique described in Chapter 1 (Mayes *et al.* 1986a; Dove and Mayes, 1991) was used for this purpose. Intake estimates using the $C_{31}$-$C_{32}$ and $C_{32}$-$C_{35}$ alkane pairs were compared with the conventionally used $C_{32}$-$C_{33}$ alkane pair. Digestibility was estimated using the $C_{31}$, $C_{33}$, and $C_{35}$ herbage alkanes individually.

## 3.2 Materials and Methods

### 3.2.1 Treatments and experimental design

Two experiments were carried out during the trial, to determine intake and digestibility using the double alkanes technique. The first experiment (5-18 Dec. 1994) was conducted during the grass only period of the trial, and the second (9-22 Feb. 1995) during the concentrate period. All sixteen heifers were dosed with alkanes in both the first and second experiments. Thus, there were two treatments of eight animals each during the first experiment, whilst the second experiment consisted of one treatment of eight animals and two treatments of four animals each.

### 3.2.2 Dose preparation

The dosed alkane ($C_{32}$) was coated onto milled grass and dosed to animals in suspension form by means of a dosing gun (Marais *et al.*, 1995).

#### *3.2.2.1 Coating grass with the alkane*

Dry hay was finely milled, before being passed through a 0.5mm sieve, followed by a 0.2mm sieve. Material of between 0.2 and 0.5mm was, thus, collected and this was used as a solid support onto which the alkanes were coated. This, ensured that the selected material had a relatively even particle size distribution. Material passing through the 0.2mm sieve was discarded because it was too fine, whilst that which remained in the 0.5mm sieve was returned for re-milling.

The milled hay (50g) was placed in a one litre rotary evaporator flask together with 350ml petroleum ether (60-80$^0$C boiling point), in which 5g dotriacontane ($C_{32}$) had been dissolved. The suspension was evaporated to dryness on a rotary evaporator at 40$^0$C. Traces of petroleum ether were removed from the coated grass by heating overnight in an oven at 60$^0$C. The coated grass was then passed through a 1mm sieve to remove any lumps. This process was repeated until a sufficiently large quantity of coated grass was obtained. Samples of coated grass were taken from randomly selected replicates (batches) for determination of $C_{32}$ content.

#### *3.2.2.2 Suspension preparation*

One hundred and ten grammes of the coated grass were added to two litres of a 0.4% solution of xanthan gum (Keltrol GM, Merck & Co., Inc. (Rahway, NJ), Kelco Div., USA). The xanthan gum served as a viscosifying agent allowing retention of the milled grass particles in suspension. It was essential to ensure an even distribution of grass particles throughout the suspension, as the alkane was associated with a solid support and not with the liquid. For this reason, suspensions were prepared not more than 24 hours before the time of dosing to prevent an accumulation of coated grass particles settling at the bottom of the suspension. Suspensions were also vigorously shaken immediately prior to dosing.

## 3.2.3 Dosing and faecal collection in the field

### *3.2.3.1 Dosing procedures*

Animals were dosed once daily with the prepared alkane suspension for 14 days consecutively (Plate 6). One hundred millilitres of alkane suspension, theoretically containing 0.5g $C_{32}$, was dosed per animal per day using a dosing gun with a wide tip and without a one way flow valve. A narrow tip or valve could lead to preferential retardation of the grass particles. Dosing was done at approximately 8:00h each day.

### *3.2.3.2 Faecal collection procedures*

Faecal sampling was achieved by taking rectal grab samples twice daily commencing on the eighth day of dosing and continuing until the last day of dosing on day 14. The seven days of dosing prior to faecal collection served to stabilise the level of the dosed alkane in the digestive tract. Faecal sampling was done at 8:00h and 16:00h daily (Plate 7). Daily morning and afternoon samples taken for each animal were pooled. Animal no. 36 (Hereford) had to be removed from the second experiment after day 3 due to a rectal abscess.

## 3.2.4 Herbage sampling

Two hand-plucked herbage samples were taken daily, commencing three days before the first day of faecal collection and continuing until the end of each experiment. In the absence of oesophageal fistulas, an attempt was to hand-pluck samples as representative of the grazed herbage as possible. As mentioned in Chapter 2, this technique is somewhat subjective. Rotation of animals between camps during the first experiment may have accentuated this effect. During the second experiment the animals remained in one camp over the duration of the faecal collection period.

**Plate 6.** Experimental animal being dosed with alkane suspension

**Plate 7.** Faecal collection from one of the experimental animals

### 3.2.5 Storage of faecal samples

Pooled faecal samples were stored after collection owing to the laboratory staff being unable to extract the samples at the time of collection. Samples were heat-sealed in labelled plastic bags and frozen on the day of collection. Following several weeks in cold storage, samples were thawed and oven-dried at 70°C for approximately 48 hours. Dried samples were then milled through a 0.5mm grid and stored in labelled bottles.

### 3.2.6 Laboratory analysis for alkane content of samples

Extraction and quantification of n-alkanes in the herbage, feed, faeces and coated grass samples was performed at Cedara Research Station using a technique developed by Marais (1995). Alkanes were extracted using organic solvents. Substances co-extracted with the alkanes were removed by binding the substances to silica gel and preferentially eluting the alkanes with hexane. The alkanes were subsequently separated and quantitated by means of gas chromatography.

#### *3.2.6.1 Extraction procedures*

Extraction of n-alkanes from herbage, feed and faeces is detailed in step form as follows:

(i) An alkane internal standard was created by dissolving 0.2g of hexatriacontane ($C_{36}$) up to 100g with undecane.

(ii) The alkane internal standard (0.2g) was weighed into a 50ml glass-stoppered test-tube to which 1g of faeces sample or 1.5 g of grass / feed were added.

(iii) Forty millilitres petroleum ether (80 - 100°C boiling pt.) were added and the tube heated in a water-bath at 70°C for 2h with occasional shaking.

(iv) Once the residue had settled, the supernatant solvent was decanted into a 50 ml beaker and evaporated to dryness.

(v) The dried extract was dissolved in 2ml petroleum ether (60-80°C boiling pt.) and applied to the top of a column containing silica gel with a bed volume of 5ml.

(vi) Alkanes were eluted into a small test-tube using hexane (10ml).

(vii) The elute was evaporated to dryness.

(viii) Extracted alkanes were dissolved in hexane (0.6ml) and an aliquot (1$\mu$l) was applied to a gas chromatogram column (megabore, 30m, 100% methyl polysiloxane, 1.5 micron, temperature programme 120$^0$C for 3 min. rising to 240$^0$C at 110$^0$ C/min, final temperature 298$^0$C at 80$^0$ C/min. Hold time 5 min Injector temperature - 305$^0$ C : Detector temperature 335$^0$ C. Flow rate 3.45 x 10$^4$ Pa).

Coated grass samples were extracted using the same procedure as outlined above, except that 0.5g of sample and 10g of alkane internal standard solution were initially added to the 50ml glass-stoppered test-tube.

### 3.2.7 Statistical analysis

Intake and digestibility results were analysed by analysis of variance using Genstat (1987). The levels of significance of the main and interaction effects were determined using F-tests. Differences between means for treatments, days and alkane pairs used to estimate intake (methods) were tested using the Students t-test at the 1 and 5% levels, within the two-way interaction tables. The effect of day on digestibility was not assessed as the objective was to ascertain breed differences in the mean digestibility estimate over several days.

## 3.3 Results

### 3.3.1 Levels of n-alkanes in administered doses

The coated alkane ($C_{32}$) did not bind well to the grass support during the rotary evaporation process, resulting in the mean $C_{32}$ concentration per dose (311, and 349mg for the first and second experiments, respectively) being considerably lower than the desired level of 500 mg (Table 3.1). A low vacuum pressure in the rotary evaporator used, resulting in a portion of the $C_{32}$ preferentially binding with the sides of the evaporator flask rather than onto the grass support, is thought to have been a major cause of loss of $C_{32}$ from the system. The use of finely milled hay rather than oven-dried kikuyu as a solid support may have influenced the capacity of the alkane to bind with the support, although this is unlikely.

Variation in the concentration of $C_{32}$ between batches was high. Marais *et al.* (1995) estimated the CV% for the mean concentration of $C_{32}$ determined from eight batches of coated grass to be ±2%, whereas in the second experiment of the current trial (using an equivalent number of batches to determine the mean $C_{32}$ concentration), the CV% was far higher (7%) than this estimate. The lower CV% for the concentration of $C_{32}$ between the coated grass samples in the second experiment compared to the first (7.04 vs. 15.29%) is probably largely due to a lower number of coated grass samples in the first experiment. Thorough mixing of all batches prior to dosing for each of the two experiments was expected to result in a uniform concentration of $C_{32}$ throughout the pooled coated grass (from which doses were prepared). If this were true, the CV% for the level of $C_{32}$ administered per dose would be dependent solely on variation in the mass of coated grass dispensed by the dosing gun. This was estimated by Marais *et al.* (1995) (for the dosing gun used in this trial) to be approximately 2.6% (Table 3.1).

**Table 3.1.** The concentration of $C_{32}$ in coated grass samples (mg/kg) and the estimated mean content of $C_{32}$ in the doses administered (mg/dose).

| **Experiment 1** | | |
|---|---|---|
| Batch | $C_{32}$ (mg/kg) | $C_{32}$ (mg/dose) |
| 1 | 56786 | |
| 2 | 59073 | |
| 3 | 73768 | |
| 4 | 76960 | |
| Mean (coated grass) | 66647 | |
| CV % | 15.29 | |
| Mean dose[1] | | 311.42 |
| CV %[2] | | 2.60 |
| **Experiment 2** | | |
| 5 | 75024 | |
| 6 | 73026 | |
| 7 | 75077 | |
| 8 | 71379 | |
| 9 | 67499 | |
| 10 | 80221 | |
| 11 | 70772 | |
| 12 | 83703 | |
| Mean (coated grass) | 74588 | |
| CV % | 7.04 | |
| Mean dose[1] | | 348.63 |
| CV %[2] | | 2.60 |

[1] correction factor (0.935) applied due to consistent under-dosing by gun (n = 5)

[2] variation in the mass of coated grass delivered per dose by the dosing gun (Marais *et al.*, 1995)

### 3.3.2 Level of n-alkanes in the herbage

The alkane $C_{32}$ was present in the herbage in considerably lower concentrations than any of the three odd-chain length alkanes measured (Table 3.2). Of the odd-chain length alkanes, $C_{33}$ was the most prevalent. The level of herbage alkane in experiment 1 was significantly higher for $C_{32}$ ($P < 0.05$), $C_{33}$ ($P < 0.01$) and $C_{35}$ ($P < 0.01$) than in experiment 2. Herbage $C_{31}$ levels were, however not significantly different ($P > 0.05$) between experiments.

**Table 3.2.** The mean concentrations of n-alkanes ($C_{31}$, $C_{32}$, $C_{33}$ and $C_{35}$) in the herbage sampled for trial 1, and trial 2 (mg/kg; n = 18).

| | Herbage n-alkane | | | |
|---|---|---|---|---|
| Experiment | $C_{31}$ | $C_{32}$ | $C_{33}$ | $C_{35}$ |
| 1 (n=18) | 126.27 | 17.27 | 189.54 | 109.87 |
| CV | 0.22 | 0.17 | 0.19 | 0.10 |
| 2 (n=18) | 132.97 | 22.14 | 253.75 | 185.29 |
| CV | 0.15 | 0.36 | 0.09 | 0.15 |
| Difference | -6.70 | -4.87 | -64.21 | -75.42 |
| Significance[1] | NS | * | ** | ** |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

### 3.3.3 Intake estimation

The intake of kikuyu (DM) was calculated from the levels of n-alkanes in the herbage (Appendix 9) and faeces (Appendix 10) using equation (6).

#### *3.3.3.1 Model suitability*

Examination of the residual plots for the intake data relating to experiments 1 and 2 (Appendix 11A) indicated heterocedascity for both experiments, with the results indicating that, for the different treatments, standard errors were proportional to the means. Analysis of variance assumes that residual variance is constant over the range of fitted values and, hence, a log transformation of the dependent variate was performed. Log transformation successfully corrected the distribution of the residuals, resulting in relatively constant pattern of residual variance (Appendix 11B). It is to be noted; comparing the results from the two-way interaction tables (Tables 3.3, 3.4 and 3.5, with those presented in Appendix 11C), that there was little change in the significance of the various comparisons. Comparison of the ANOVA tables (Appendix 11D and 11E) suggested that an improvement in the precision of the statistical analyses was the only clear effect of the transformation. There was no real change in the significance levels of the various main effects and interactions. For convenience, therefore, the results which follow are from the analysis of the untransformed data.

A feature of concern in the intake data collected in experiment 1 was the high level of variation in intake between days. The levels of the dosed even-chain length alkane and the naturally occurring odd-chain length alkane in the faeces are the only two variables in the calculation of intake (using equation (6)) between days, and between animals within the chosen alkane pair. Hence, the level of intake will increase (although not in direct proportion) as the faecal ratio of the odd-chain length alkane to the even-chain length alkane increases. The level of this ratio expressed as a proportion of the mean over the period of faecal collection has been used to determine the length of the dosing period required prior to faecal collection in order for the dosed alkane to reach stable levels in the digestive tract (Mayes *et al.*, 1986a). It would, therefore, seem logical that abnormally high or low ratios of the chosen odd-chain length alkane to the dosed even-chain length alkane in the faeces, when expressed as a mean over the period of faecal collection, may be indicative of some form of experimental error. This could be either in the dosing procedure, or in obtaining a representative sample of the herbage consumed. In addition, the trend towards increasing residual variance as the level of intake increased suggests that the accuracy of intake determination may have declined at high levels of intake.

The faecal alkane ratio in experiment 1 departed from the 25% boundary surrounding the mean on day 4 of faecal collection where either the $C_{31}$:$C_{32}$ or the $C_{33}$:$C_{32}$ faecal alkane ratios were used to estimate intake (Figure 3.1). Variation about the mean for day 4 was also higher than that for any other day. This ratio was also greater than 25% of the mean on day 5 for $C_{31}$:$C_{32}$ but not for $C_{33}$:$C_{32}$. The pattern of the faecal alkane ratio of $C_{35}$:$C_{32}$, expressed as a proportion of the mean over the seven days of faecal collection, differed greatly from either the $C_{31}$:$C_{32}$ or the $C_{33}$:$C_{32}$

ratios, although a relatively high level of the ratio on day 4 was consistent between alkane pairs. It was, however, expected that the use of $C_{35}$ as the odd-chain alkane would give the least reliable estimates of intake owing to the predicted relatively large disparity in the faecal recoveries of the odd- and even-chain length alkanes. The high faecal alkane ratios on days 4 and 5 were clearly influenced by experimental error and were, thus, removed from the analysis. Variation arising from the interaction term *breed.method* remained non-significant ($P > 0.05$), both before and after removal of days 4 and 5 from the analyses. This demonstrated that breed differences remained consistent between the different methods used to estimate intake.

The mean faecal ratios of $C_{31}$:$C_{32}$ and $C_{33}$:$C_{32}$ remained within a narrower range about the mean in experiment 2 compared to experiment 1 (Figure 3.2). Consistent with trial 1, however, the ratio of $C_{35}$:$C_{32}$ followed a very different pattern over the faecal collection period compared to the former two alkane pairs. Although the faecal ratio of $C_{35}$:$C_{32}$ reached very high, and low levels compared to the mean on days 1 and 3 of faecal collection, these days were not dropped from the model due to the predicted low reliability of $C_{35}$ in estimating intake compared to $C_{31}$ and $C_{33}$.

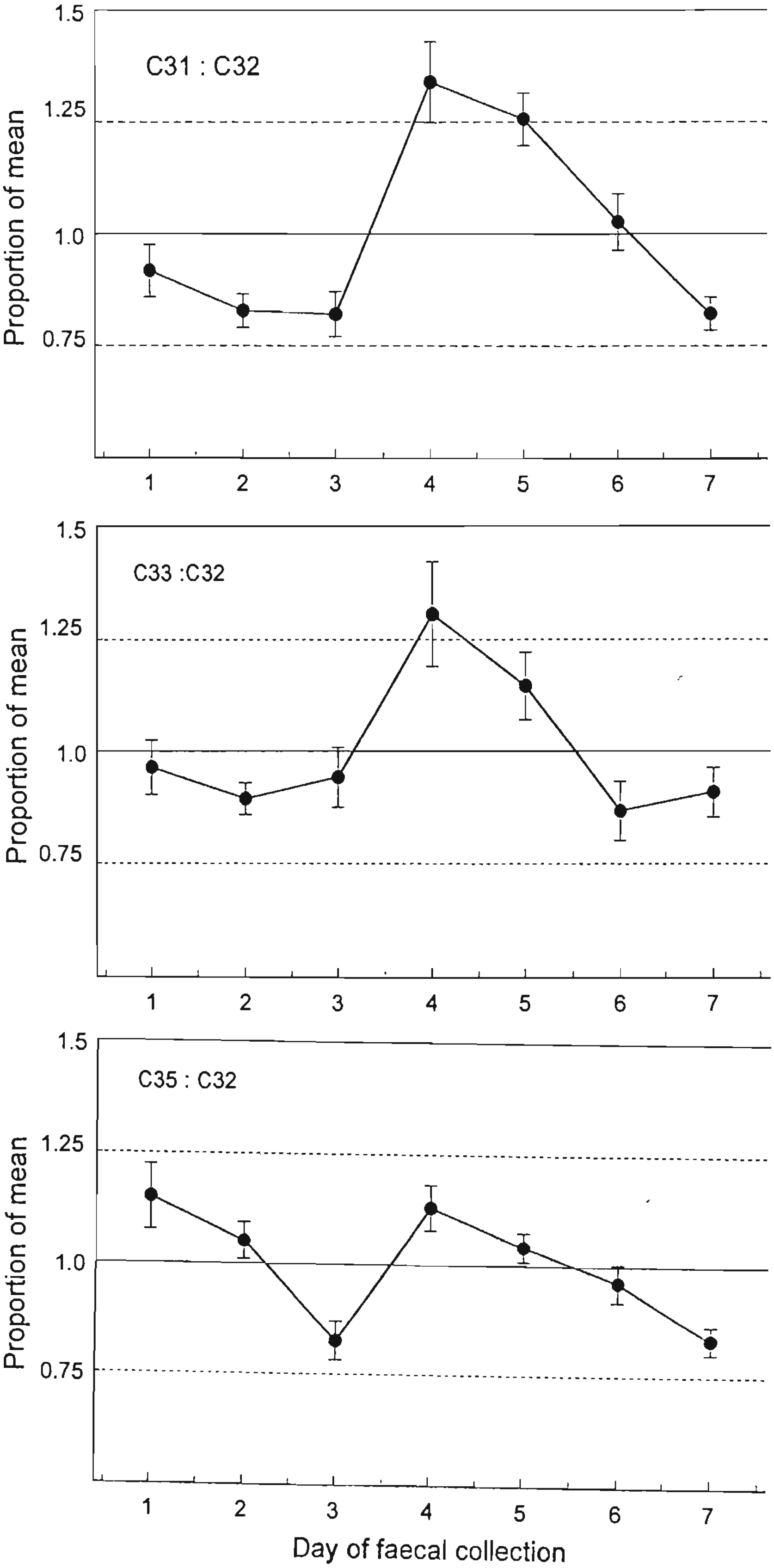

**Figure 3.1**. Changes in mean ratio of odd-chain (herbage) n-alkane concentrations to even-chain (dosed) n-alkane concentrations with time (days) after commencement of faecal collection in experiment 1. Values are expressed as proportions of the mean for each heifer (± S.E.M.; n=16).

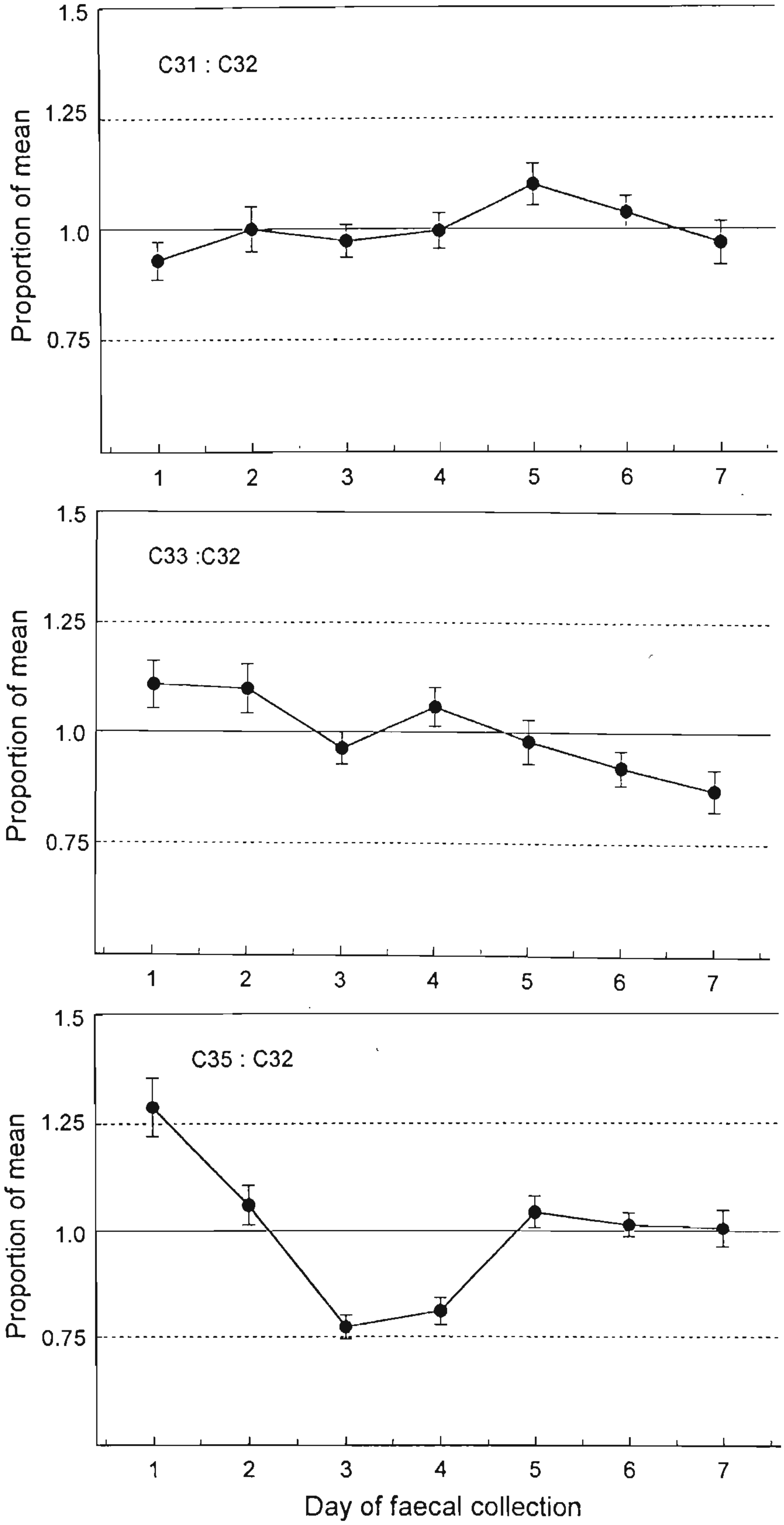

**Figure 3.2.** Changes in mean ratio of odd-chain (herbage) n-alkane concentrations to even-chain (dosed) n-alkane concentrations with time (days) after commencement of faecal collection in experiment 2. Values are expressed as proportions of the mean for each heifer (± S.E.M.; n=16).

### *3.3.3.3 Differences between treatments*

The *breed.method* interaction was not significant ($P > 0.05$) for either of the two experiments (F-test; Appendix 11D). This demonstrates that intake was consistently different between treatments over the methods used. The mean intake of kikuyu (DM) in experiment 1, expressed per unit metabolic mass, was significantly higher for the Hereford treatment relative to the Holstein treatment ($P < 0.01$) for all of the three alkane pairs used to estimate intake (Table 3.3). Herbage intake per unit metabolic mass for the Herefords exceeded that of the Holsteins by 55% ($P < 0.01$; Table 3.3) in the first experiment.

Addition of concentrate to the diet (19.59 g/kg $LW^{075}$) reduced the intake of grass for the Herefords. Although the $C_{31}$-$C_{32}$ alkane pair was the only method used to demonstrate a significant difference ($P < 0.05$) for this comparison, the mean difference in estimated intake from all three alkane pairs was significant ($P < 0.01$). DM intake of kikuyu was, on average, depressed by 21% when concentrate was added to the diet. The Herefords recieving concentrate in the second experiment had a significantly higher (23%; $P < 0.01$) DM intake of kikuyu than the Holsteins (consuming a mean of 13.97 g of concentrate/kg $LW^{0.75}/d^1$). This was determined by the use of the $C_{32}$-$C_{33}$ alkane pair, and the mean of all three methods. The Hereford treatment grazing *ad lib.* kikuyu without concentrate had a significantly (49%; $P < 0.01$) higher herbage intake than the Holsteins for all methods used to estimate intake in the second experiment.

**Table 3.3**. Treatment mean intakes of kikuyu (DM) (g/kg L.W.$^{0.75}$/d) estimated using the $C_{32}$-$C_{33}$, $C_{31}$-$C_{32}$, and $C_{32}$-$C_{35}$ alkane pairs.

| **Experiment 1** | Method of intake determination | | | |
|---|---|---|---|---|
| Treatment | $C_{32}$-$C_{33}$ | $C_{31}$-$C_{32}$ | $C_{32}$-$C_{35}$ | Means |
| Hereford | 206.8 | 143.8 | 205.7 | 185.4 |
| Holstein | 121.1 | 93.2 | 147.2 | 120.5 |
| Means | 163.9 | 118.5 | 176.4 | 153.0 |
| Difference | 85.7 | 50.6 | 58.5 | 64.9 |
| S.E.D. | 16.4 | | | 9.47 |
| Significance[1] | * * | * * | * * | * * |
| **Experiment 2** | | | | |
| Hereford[2] (1) | 141.7 | 112.4 | 163.2 | 139.1 |
| Hereford[3] (2) | 167.2 | 146.9 | 190.5 | 168.2 |
| Holstein (3) | 105.4 | 95.9 | 138.2 | 113.2 |
| Mean | 129.9 | 112.8 | 157.5 | 133.4 |
| Difference (1-2) | -25.5 | -34.5 | -27.3 | -29.1 |
| S.E.D. | 14.87 | | | 8.59 |
| Significance[1] | NS | * | NS | * * |
| Difference (2-3) | 61.8 | 51.0 | 52.3 | 55.0 |
| S.E.D. | 12.88 | | | 7.44 |
| Significance[1] | * * | * * | * * | * * |
| Difference (1-3) | 36.3 | 16.5 | 25.0 | 25.9 |
| S.E.D. | 12.88 | | | 7.44 |
| Significance[1] | * * | NS | NS | * * |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

[2] Hereford treatment receiving concentrate in addition to *ad libitum* kikuyu pasture

[3] Hereford treatment receiving *ad libitum* kikuyu pasture alone

### *3.3.3.4 Differences between days*

There was significant variation between days ($P < 0.05$) in the intake of kikuyu (expressed as a mean of all methods for all of the sixteen trial animals) in both experiments (Table 3.4). Significance of the *breed.days* interactions (F-tests; $P < 0.001$; Appendix 11D) for both experiments suggests that grazing patterns differed between treatments. The first experiment, thus, suggests that the two breeds followed different grazing patterns over the five days of faecal collection analysed. A significantly higher intake ($P < 0.05$) for the Herefords than the Holsteins, however, consistent over all five days studied. There was a progressive decline in herbage intake over the first three days of faecal collection, consistent with declining intake as the pasture was grazed down prior to pasture rotation.

Herbage intake by the Hereford treatment receiving concentrate was significantly higher than that of the Holstein treatment over four of the seven days within the second experiment. The addition of concentrate to the diet of the Herefords, however, depressed intake significantly over only four days compared to the Hereford treatment consuming grass alone. It would, thus, seem probable that the addition of concentrate to the diet caused a significant difference in grazing pattern within the Hereford breed. A tendency towards declining intake as the days advanced in experiment 2 was difficult to ascertain. Such a trend was anticipated due to the fact that the heifers were grazed on the same pasture over the faecal collection period.

### *3.3.3.5 Differences between methods*

The mean intake of all the experimental animals was significantly different between methods ($P < 0.05$ and $P < 0.01$) used to estimate intake for both experiments. Intake was estimated from the highest to lowest using the $C_{32}$-$C_{35}$, $C_{32}$-$C_{33}$, and $C_{31}$-$C_{32}$ alkane pairs, respectively (Table 3.5). The difference between mean intake estimated using the $C_{32}$-$C_{35}$ and the $C_{32}$-$C_{33}$ alkane pairs was, however, not statistically different for the first experiment. Significance of the *method.days* interaction (F-test; $P < 0.001$; Appendix 11D) for both experiments implies that the various alkane pairs used were not consistent in estimating intake between days.

**Table 3.4**. Treatment mean intakes of kikuyu (DM) (g/kg L.W$^{0.75}$/d) by day over the faecal collection period, estimated using the mean of the $C_{31}$-$C_{32}$, $C_{32}$-$C_{33}$, and $C_{32}$-$C_{35}$ alkane pairs.

| **Experiment 1** | Day of faecal collection | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean | S.E.D. |
| Hereford | 217.5 | 171.0 | 159.6 | | | 208.5 | 134.2 | 185.4 | |
| Holstein | 144.2 | 133.1 | 118.3 | | | 109.0 | 98.0 | 120.5 | |
| Mean[1] | $180.8^{a}$ | $152.0^{bc}$ | $139.0^{bc}$ | | | $158.8^{ab}$ | $134.2^{c}$ | 153.0 | 9.07 |
| Difference | 73.3 | 37.9 | 41.3 | | | 99.5 | 36.2 | 64.9 | |
| S.E.D. | 14.87 | | | | | | | 9.47 | |
| Significance[2] | ** | * | ** | | | ** | * | ** | |
| **Experiment 2** | | | | | | | | | |
| Hereford[3] (1) | 180.4 | 124.7 | 92.2 | 137.6 | 174.6 | 143.8 | 120.6 | 139.1 | |
| Hereford[4] (2) | 247.1 | 177.4 | 123.9 | 142.7 | 164.5 | 152.2 | 169.5 | 168.2 | |
| Holstein (3) | 126.2 | 136.0 | 102.7 | 101.1 | 115.3 | 110.1 | 100.7 | 113.2 | |
| Mean[1] | $170.0^{a}$ | $143.5^{b}$ | $105.4^{d}$ | $120.6^{c}$ | $142.4^{b}$ | $129.0^{bc}$ | $122.9^{c}$ | 133.4 | 6.05 |
| Difference (1-2) | -66.7 | -52.7 | -31.7 | -5.1 | 10.1 | -8.4 | -48.9 | -29.1 | |
| S.E.D. | 14.12 | | | | | | | 8.59 | |
| Significance[2] | ** | ** | * | | | | ** | ** | |
| Difference (2-3) | 120.9 | 41.4 | 21.2 | 41.6 | 49.2 | 42.1 | 68.8 | 55.0 | |
| S.E.D. | 12.23 | | | | | | | 7.44 | |
| Significance[2] | ** | ** | | ** | ** | ** | ** | ** | |
| Difference (1-3) | 54.2 | -11.3 | -10.5 | 36.5 | 59.3 | 33.7 | 19.9 | 25.9 | |
| S.E.D. | 12.23 | | | | | | | 7.44 | |
| Significance[2] | ** | | | ** | ** | ** | | ** | |

[1] values with different superscripts (within an experiment) differ significantly ($P < 0.05$)

[2] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

[3] Hereford treatment receiving concentrate in addition to *ad libitum* kikuyu pasture

[4] Hereford treatment receiving *ad libitum* kikuyu pasture alone

**Table 3.5.** Mean intake of kikuyu (DM) (g/kg L.W$^{0.75}$/d) by day over the faecal collection period for the $C_{32}$-$C_{33}$, $C_{31}$-$C_{32}$, and $C_{32}$-$C_{35}$ alkane pairs.

| **Experiment 1** | Day of faecal collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Method | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| $C_{32}$-$C_{33}$ (1) | 177.1 | 150.7 | 175.8 | | | 154.5 | 161.6 | 163.9 |
| $C_{31}$-$C_{32}$ (2) | 125.0 | 105.9 | 106.4 | | | 150.2 | 105.0 | 118.5 |
| $C_{32}$-$C_{35}$ (3) | 240.4 | 199.4 | 134.8 | | | 171.7 | 135.9 | 176.4 |
| Mean | 180.8 | 152.0 | 139.0 | | | 158.8 | 134.2 | 153.0 |
| Difference (1-2) | 52.1 | 44.8 | 69.4 | | | 4.3 | 56.6 | 45.4 |
| S.E.D. | 18.21 | | | | | | | 11.59 |
| Significance[1] | * | * | * * | | | NS | * * | * * |
| Difference (2-3) | -115.4 | -93.5 | -28.4 | | | -21.5 | -30.9 | -57.9 |
| Significance[1] | * * | * * | NS | | | NS | NS | * * |
| Difference (1-3) | -63.3 | -48.7 | 41.0 | | | -17.2 | 25.7 | -12.5 |
| Significance[1] | * * | * * | (*)[2] | | | NS | NS | NS |
| **Experiment 2** | | | | | | | | |
| $C_{32}$-$C_{33}$ (1) | 152.5 | 151.2 | 118.2 | 141.5 | 129.0 | 112.8 | 104.0 | 129.9 |
| $C_{31}$-$C_{32}$ (2) | 100.5 | 113.5 | 105.3 | 111.9 | 132.2 | 119.1 | 107.0 | 112.8 |
| $C_{32}$-$C_{35}$ (3) | 256.9 | 165.9 | 92.7 | 108.4 | 166.0 | 155.2 | 157.6 | 157.5 |
| Mean | 170.0 | 143.5 | 105.4 | 120.6 | 142.4 | 129.0 | 122.9 | 133.4 |
| Difference (1-2) | 52.0 | 37.7 | 12.9 | 29.6 | -3.2 | -6.30 | -3.0 | 17.1 |
| S.E.D. | 12.23 | | | | | | | 7.44 |
| Significance[1] | * * | * * | NS | * | NS | NS | NS | * |
| Difference (2-3) | -156.4 | -52.4 | 12.6 | 3.5 | -33.8 | -36.1 | -50.6 | -44.7 |
| Significance[1] | * * | * * | | | * * | * * | * * | * * |
| Difference (1-3) | -104.4 | -14.7 | 25.5 | 33.1 | -37.0 | -42.4 | -53.6 | -27.6 |
| Significance[1] | * * | NS | * | * * | * * | * * | * * | * * |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

[2] parantheses indicate comparisons which were not significant before log transformation

### 3.3.4 Digestibility estimation

#### *3.3.4.1 Model suitability*

The distribution of the residuals for digestibility in both experiments 1 and 2 appeared consistent compared with the residuals for intake (Appendix 12A), and transformation of the dependent variate was, therefore, unnecessary for either experiment

Data were not dropped for any days in the statistical analysis of digestibility for either of the two trials. Excessively high ratios of the herbage odd-chain alkane to the dosed even-chain alkane in the faeces indicated some justification for the removal of the intake data of days 4 and 5 from experiment 1. This was due, in part, to a decline in the faecal levels of the dosed alkane and, in part, due to an increase in the level of the herbage odd-chain alkane. The latter cause clearly influences the estimation of digestibility, whilst the former has no influence on the calculation of digestibility (using equation (3)). Excessively high or low daily means for digestibility are a result of the animals grazing herbage with either a far greater or, alternatively, a far lower alkane content than the mean of the herbage sampled. On the assumption that the herbage selected was similar for both breeds, this effect should have influenced the digestibility of the Herefords and the Holsteins equally in experiment 1. The constant distribution of the residuals relating to digestibility in both experiments suggests that variation about the mean should not have increased as the mean daily digestibility value for a given treatment increased. There was, thus, little theoretical justification for dropping days where a comparison of digestibility between treatments was the objective.

#### *3.3.4.2 Differences between treatment groups*

The mean digestibility of all experimental animals increased as the chain length of the herbage alkane increased. However, these differences were not always significant (Table 3.6). Although the digestibility of the grazed kikuyu (DM) was estimated as being significantly higher for the Herefords than the Holsteins in trial 1, where $C_{31}$ and $C_{33}$ were used to estimate digestibility ($P < 0.05$), $C_{35}$ showed the mean digestibility estimates (68.46 vs 68.19 for the Herefords and Holsteins, respectively) to be similar between breeds ($P > 0.05$).

**Table 3.6**. Digestibility (%) of the kikuyu (DM) estimated using the $C_{31}$, $C_{33}$ and $C_{35}$ herbage alkanes.

| **Experiment 1** | Method of digestibility determination | | | | |
|---|---|---|---|---|---|
| Treatment | $C_{31}$ | $C_{33}$ | $C_{35}$ | Mean | S.E.D. |
| Hereford | 63.93 | 70.05 | 68.46 | 67.48 | |
| Holstein | 59.88 | 64.47 | 68.19 | 64.18 | |
| Mean[1] | $61.91^b$ | $67.26^a$ | $68.32^a$ | 65.83 | 1.196 |
| Difference | 4.05 | 5.58 | 0.27 | 3.30 | |
| S.E.D. | 1.692 | | | 0.977 | |
| Significance[2] | * | * * | NS | * * | |
| **Experiment 2** | | | | | |
| Hereford[3] (1) | 51.71 | 57.49 | 59.84 | 56.35 | |
| Hereford[4] (2) | 57.70 | 59.68 | 60.81 | 59.40 | |
| Holstein (3) | 48.76 | 51.16 | 58.85 | 52.92 | |
| Mean[1] | $51.73^b$ | $54.87^b$ | $59.59^a$ | 55.40 | 1.646 |
| Difference (1-2) | -5.99 | -2.19 | -0.97 | -3.05 | |
| S.E.D. | 3.292 | | | 1.900 | |
| Significance[2] | NS | NS | NS | NS | |
| Difference (2-3) | 8.94 | 8.52 | 1.96 | 6.48 | |
| S.E.D. | 2.851 | | | 1.646 | |
| Significance[2] | * * | * * | NS | * * | |
| Difference (1-3) | 2.95 | 6.33 | 0.99 | 3.43 | |
| S.E.D. | 2.851 | | | 1.646 | |
| Significance[2] | NS | * | NS | * | |

[1] values with different superscripts (within an experiment) differ significantly ($P < 0.05$)

[2] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

[3] Hereford treatment receiving concentrate in addition to *ad libitum* kikuyu pasture

[4] Hereford treatment receiving *ad libitum* kikuyu pasture alone

The addition of concentrate to the diet of the Herefords clearly resulted in no significant change ($P > 0.05$) in the herbage component of the diet. The herbage DM digestibility was shown to be higher for the Herefords receiving concentrate than the Holsteins in experiment 2 using the $C_{33}$ herbage alkane. However, differences were not significant ($P > 0.05$) where $C_{31}$ or $C_{35}$ was used to estimate digestibility. Non-significance of the term *breed.method* (F-test; $P > 0.05$) (Appendix 12B) for both experiments demonstrates that the various odd-chain length alkanes were not consistent in estimating digestibility differences between treatments in either of the experiments.

### *3.3.4.3 Relative faecal recoveries of n-alkanes*

Estimation of the relative faecal recoveries of the three odd-chain length alkanes was achieved by comparison of their predicted digestibility values, expressed as a mean for all animals, within each of the two experiments. Owing to the fact that the three odd-chain length alkanes used to compare digestibility were extracted from the same faecal samples within either of the two experiments, and that the level of the respective odd-chain length alkane in the faeces is the only variable in the calculation of digestibility, differences in the estimation of digestibility between methods should have been directly proportional to differing faecal recovery between alkanes. The faecal recovery of $C_{35}$, assumed to be 0.95 (Dove and Mayes, 1991), was used as a basal value against which the recovery of $C_{31}$ and $C_{33}$ were compared. Although the faecal recovery of pentatriacontane ($C_{35}$) was determined using sheep, it is expected that recovery in cattle would be similar.

The recovery pattern of the odd-chain length alkanes was similar between experiments (Table 3.7). The difference in faecal recovery between $C_{35}$ and $C_{33}$ was lower than that between $C_{33}$ and $C_{31}$.

**Table 3.7.** Estimated faecal recovery values for $C_{31}$, $C_{33}$ and $C_{35}$ for replication 1 and 2.

| | Herbage odd-chain length alkane | | |
|---|---|---|---|
| Experiment | $C_{31}$ | $C_{33}$ | $C_{35}$ |
| 1 | 86.05 | 92.66 | 95.00 |
| 2 | 88.63 | 93.95 | 95.00 |

## 3.4 Discussion

### 3.4.1 Intake

A study of the relevant literature shows that the intake of kikuyu (DM) was clearly over-estimated in both experiments using the double alkanes technique. Dugmore and du Toit (1988) showed the mean voluntary DMI of cut kikuyu (in 17 digestibility trials using 6 Hereford steers per trial) to be 1.95% (±0.21) of body mass, which translates to 52.18 g/kg L.$W^{0.75}$. Joyce (1974) found similar results with sheep fed cut kikuyu in stalls, showing DMI to vary between 53.5 and 54.3 g/kg L.$W^{0.75}$. The mean estimated intakes of 153.0 and 133.4 g/kg L.$W^{0.75}$ for the first and second experiments, respectively, greatly exceed these values. In addition, it should not be forgotten that concentrate was consumed together with the grazed herbage in the second trial. The DMI of animals grazing kikuyu may, however, be different to those fed in stalls. Pattinson (1981) estimated the intake of steers grazing kikuyu (using chromic oxide as a marker) to be 107.61 g/kg L.$W^{0.75}$ in December, before the autumn slump in herbage quality. DMI in the present trial would be 42 and 24% higher than this estimate for the first and second experiments respectively. In the absence of known DMI, it is difficult to estimate the extent by which the double alkanes technique over-estimated intake. The estimated requirement of ME from the kikuyu DM to achieve recorded growth rates over the grass only period (as estimated from ARC (1980) standards) suggests a mean DMI of 86.5 g/kg L.$W^{0.75}$, 77% lower than that estimated using the double alkanes technique. As discussed in Chapter 2, there may, however, have been considerable variation in DMI between camps during this period of the trial.

The DMI of grazed kikuyu herbage was clearly higher for the Herefords than the Holsteins in the first experiment. The estimated mean difference in intake between breeds of 55% is high, but is consistent with the large differences in ME requirements required to achieve the greatly divergent growth rates between the two breeds over the grass only period of the trial. The significantly reduced herbage intake ($P < 0.01$) when concentrate was added to the diet of the Herefords is consistent with the suspected substitution effect discussed in Chapter 2. The mean concentrate intake of the Herefords in the second experiment supplied 16.33 MJ ME/day. If this ME substituted completely for the ME provided in the grazed kikuyu (9 MJ/kg), then the growth rates achieved suggest that herbage intake may have declined by 23.26% (ARC, 1980). Intake of the Herefords receiving concentrate was estimated, using the mean of the three alkane pairs, to be 21% lower than the Hereford control treatment. It would, thus, seem likely that substitution of concentrate for grass was almost complete. The lower magnitude of the difference in DMI between Herefords and Holsteins, when both breeds were receiving concentrate (22.9%), compared to when both breeds were grazing kikuyu alone (55.0%), is consistent with the suggestion in Chapter 2 that the substitution effect of concentrate for grass would be larger in the case of the Herefords than the Holsteins.

The ranking of the magnitude of the mean DMI estimates from highest to lowest for the three alkane pairs in the order of declining odd-chain length alkane is in agreement with the observed decline in faecal recovery as chain-length declines for the herbage alkanes. An increase in the ratio of odd- to even-chain length alkanes in the faeces will result in increased estimation of intake (equation 6). Hence, as the faecal recovery of the odd-chain length alkane increases relative to the dosed alkane, so the intake estimate would be expected to increase. It is difficult to explain why the different alkane pairs differed significantly ($P < 0.05$) in the estimation of intake between days. The ratio of odd- to even-chain length alkanes in the faeces followed similar trends over time for the $C_{31}$-$C_{32}$ and $C_{32}$-$C_{33}$ alkane pairs, but was greatly different for the $C_{32}$-$C_{35}$ alkane pair (Figures 3.1, and 3.2). A possibly lower ratio of $C_{35}$ between leaf and stem compared to $C_{31}$ and $C_{33}$ (Figure 1.2) may have resulted in selective grazing between leaf and stem having a differential effect on the $C_{35}$:$C_{32}$ ratio when compared with the $C_{31}$:$C_{32}$ and $C_{33}$:$C_{32}$ faecal alkane ratios. Accurate herbage sampling would negate this effect in the calculation of intake. However, if the herbage sampled differed greatly in the ratio of leaf to stem relative to that consumed by the experimental animals, then the pattern of intake recorded over time would be different for the $C_{32}$-$C_{35}$ alkane pair compared to the $C_{31}$-$C_{32}$ and $C_{32}$-$C_{35}$ alkane pairs.

The existence of differences between breeds in the pattern of intake between days is not documented, and there is little evidence to explain the existence of such a trend. The significance of the breed.days term ($P < 0.01$) in experiment 1 of the current trial is thus likely to have been coincidental. This may, however, be an area which requires further investigation.

### 3.4.2 Digestibility

The anticipated increasing faecal recovery of the herbage alkanes with increasing chain length, demonstrated in the present trial, suggests that $C_{35}$ was the most reliable indicator of digestibility. Hence, it is not plausible to suggest that the Herefords digested a higher proportion of the grazed kikuyu than the Holsteins, even though this effect was demonstrated by the $C_{31}$ and $C_{33}$ herbage alkanes. As there is no available evidence of differing faecal recoveries of specific alkanes between breeds of cattle, it could, however, be argued that the $C_{31}$ and $C_{33}$ herbage alkanes should have accurately reflected breed differences in digestibility of the diet, even if the absolute estimates of digestibility were under-estimated. Further investigation in this area is clearly needed.

If the faecal recovery of $C_{35}$ in the present trial was indeed 95% (Dove and Mayes, 1991), then the mean absolute digestibility of the kikuyu could be found by multiplying the obtained estimate by this value. This would yield a mean DM digestibility of 64.9% for the grazed kikuyu in the first experiment, similar to that found for sheep (61.4 to 62.0%) (Joyce, 1974) and cattle (67.2%) (Dugmore and du Toit, 1988). The mean digestibility (derived in the same manner) for $C_{35}$ in the second experiment was 56.61%, considerably lower than the first experiment. As the addition of concentrate to the diet was shown to have no significant effect on intake ($P > 0.05$), it would seem that these disparities in digestibility estimation are likely to be due to errors in herbage sampling. Higher concentrations of the herbage odd-chain length alkanes in the herbage sampled for the second experiment compared to the first (significant for $C_{33}$ and $C_{35}$) suggest a greater proportion of leaf in the herbage sampled. If the animals were in fact grazing a diet of similar concentrations of odd-chain length alkanes in the second experiment, then a decline in estimated digestibility would result.

### 3.4.3 Sources of error in intake estimation

Intake as calculated by equation (6) is dependent on the levels of various n-alkanes in the herbage, faeces and in the coated grass dosed. Failure to obtain a representative sample at each of these levels may have lead to large over-estimates of intake in the current trial.

It is clear from Chapter 1 that the double-alkanes technique of intake estimation is reliant on accurate herbage sampling such that the alkane profile of the herbage sampled is highly similar to that consumed by the animals under investigation. The herbage odd-chain length alkane was also shown to have a far greater influence on intake than the herbage even-chain length alkane. While there is a relatively large body of work testing the reliability of the technique on temperate pastures, little work has been done on tropical pastures. Animals grazing tropical pastures, such as kikuyu, tend to preferentially graze the leaf fraction. As the leaf fraction has a higher concentration of odd-chain length alkanes than the stem fraction sampling techniques which do not mimic the animal's selection of leaf and stem will adversely bias intake estimates using n-alkanes.

Vulich *et al.* (1993) found the approximate 80% confidence interval estimate of the proportionate bias in estimated intake arising from sampling variation in herbage $C_{33}$ concentration to be -0.07 to +0.07 when $C_{33}$ was estimated using three daily samples (CV 0.05) on *Lolium perenne*. It would, thus, seem probable in the current experiments where the CV's of $C_{33}$ in the herbage sampled were 0.9 and 0.19 (for the first and second experiments, respectively) and herbage samples were taken twice daily, bias in intake estimation caused by inaccurate herbage sampling may have exceeded 7% of actual intake. Bias in intake estimates due to errors in herbage n-alkane concentrations would not effect treatment comparisons, as these refer to the same sward.

In accordance with equation (6), intake will decline as the level of the herbage odd-chain length alkane increases. Thus, if the over-estimation of intake was a result of inaccurate herbage sampling, then the suggestion is that the herbage sampled may have had a higher level of stem than leaf compared to that grazed by the trial animals. As the calculation of digestibility is dependent solely on the levels of the herbage odd-chain length alkane in the herbage and faeces, provided faecal samples are representative, the precision with which digestibility is estimated should reflect the level of accuracy in herbage sampling, once a factor for incomplete faecal recovery of the alkane has been applied. Estimated herbage digestibility declines with increasing levels of the chosen odd-chain length alkane in the herbage (if the level of the odd-chain length alkane in the faeces remains fixed). Hence, lower than expected digestibility estimates in the second experiment suggest a higher mean concentration of leaf in the herbage sampled than that grazed by the experimental animals. In the first experiment, digestibility estimates similar to those reported by other workers (Joyce, 1974; Dugmore and du Toit, 1988) suggest that the alkane profile of the herbage sampled may have been representative of that consumed by the animals. It would, thus, seem logical that the over-estimation of intake is unlikely to result from a bias caused by errors in herbage sampling. It is, however, plausible that herbage sampling may have influenced errors between days.

Animals were rotated during the faecal collection period in the first but not the second experiment. The extremely high estimates of intake on days 4 and 5 of faecal collection, which were dropped from the analysis in experiment 1, could have been partially caused by pasture rotation on the second day of faecal collection. Rotation of the animals to a new camp, resulting in an increase in the ratio of available leaf to stem in the herbage, may have lead to a sudden increase in the intake of leaf as a proportion of the diet. As leaf material has a higher concentration of the herbage odd-chain length alkane, an increase in estimated intake would be the expected response. Rate of passage effects may have sufficiently delayed the passage of the herbage taken in on day 2 of faecal collection such that the response to the increased herbage odd-chain length alkane was only fully realised on day 4. Thereafter, estimated intake would slowly decrease towards its former level as the proportion of leaf in the herbage declined and animals were forced to consume a diet with concentrations of n-alkanes closer to the mean of the herbage sampled. Selection of leaf over stem may have had an effect on intake between days even where the animals were not rotated between camps during the faecal collection period. As the pasture was grazed down, there would have been a lower proportion of leaf in the forage selected and the leaves would probably also be more mature. These changes in the forage selected would lead to a decrease in the concentration of alkanes in the forage intake compared to the mean of the herbage sampled and, hence, estimated intake would decline. Under continuous grazing it is likely that animals will have access to plants previously undergrazed which have high proportions of leaf. Alternatively animals may repeatedly graze the same area and so ensure the maintenance of plants in a vegetative state resulting in a high leaf : stem ratio. Under rotational grazing animals may be forced to graze most plants available in the camp and so the proportion of stem will increase through the period of occupation.

A low daily dose of the $C_{32}$ alkane (311 and 349 mg/day for the first and second experiments, respectively), as a result of poor binding of the dosed alkane to the grass support, compared to that used by other workers (604 mg/day used by Mayes *et al.*, 1986c; and 1084 mg/day used by Malossini *et al.*, 1994) may have resulted in high levels of variation in the ratio of the faecal odd-chain length alkane to the faecal dosed alkane, due to the technique being used beyond the tested reliability range. It is not certain whether this may have biased the mean estimates of intake.

If the distribution of $C_{32}$ throughout the coated grass after the batches had been mixed was not even, then a higher than anticipated level of variation between doses would have resulted. As animals were dosed daily in random sequence, the probability is extremely low that this effect would have biased the mean intake estimate of one treatment over another. There would, however, be a greater probability that the between day variation in intake was affected due to varying levels of the dosed alkane.

A further potential source of error regarding the dosed alkane is that the mean level of $C_{32}$ in the coated grass may have been over- or under-estimated due to the samples of coated grass taken not being representative. Due to the fact that estimated intake will increase as the level of $C_{32}$ dosed daily increases (equation 6) (if all other factors remain constant), over-estimation of intake would result if the $C_{32}$ level on the coated grass was lower than that estimated from the samples taken.

Although significant diurnal variation in the ratio of various odd-chain length alkanes to the dosed even-chain alkane has been demonstrated with cattle (Dillon and Stakelum, 1989), Malossini *et al.* (1994) showed (with cattle) that one, or preferably two, daily faecal samples supplied the same information as four samples. Hence, in the present trial, pooled faecal samples based on twice daily sampling should have been sufficient. Dillon and Stakelum (1989) did, however, note that diurnal variation in the faecal alkane ratios was greater with once compared to twice daily dosing. Although once daily dosing may have resulted in faecal samples not being representative of the total faecal output, there is no reason why this effect should have differed between treatments. It is also thought that this source of error is likely to be relatively small in comparison with the errors previously discussed.

Exhaustive re-extraction of the herbage, faecal and coated grass samples revealed a high degree of consistency in the quantification of n-alkane content. It is, thus, clear that experimental error originated in the field rather than in the laboratory.

# CONCLUSION

The objectives of this study, as set out in Chapter 1, have been fulfilled as follows:

1.) Holstein heifers were found to have a significantly slower rate of mass gain than Hereford heifers on kikuyu pasture when no supplementation was given ($P < 0.01$). Although growth in height was similar between the two breeds, patterns of condition score gain and loss were not similar.

2.) Dry matter intake was found to be the dominant factor responsible for the differences in growth rates observed, whilst differences in digestibility between breeds were shown to be non-significant ($P > 0.05$).

3.) The addition of concentrate to the diet resulted in a higher growth response in the case of the Herefords relative to the Holsteins. This together with a demonstrated significant reduction ($P < 0.01$) in the intake of kikuyu for the Herefords when concentrate was offered suggests that the Herefords substituted grass for concentrate to a far larger extent than the Holsteins.

4.) The use of the double alkanes technique gave usefull results for comparative purposes, however the absolute values estimated for intake were poor. It is suggested that the technique needs to be more thoroughly tested using cattle grazing tropical pastures.

The cause of differences in dry matter intake between breeds is not evident from this trial, but it is suspected that breed differences in rate of passage may be an important factor. Retention time of digesta in, or rate of passage, from the rumen is an inherent characteristic which may respond to genetic selection. Hence if rate of passage were indeed the dominant factor influencing intake differences between breeds, then it should theoretically be possible to improve the dry matter intake of Holstein heifers grazing kikuyu through selection. Identification of the factor limiting rate of passage (such as rumen-reticular orifice diameter) would allow the progress of genetic selection to be monitored.

The growth rates of the Herefords grazing *ad lib*. kikuyu alone in the current trial are comparable to recommended growth rates for Holstein dairy heifers at similar ages. It would thus seem that if herbage intake of the Holsteins could be raised to a comparable level, then, a situation could potentially be achieved where no supplementation of Holstein heifers on kikuyu pasture would be required. As the cost of kikuyu is considerably cheaper per unit of dry matter than that of concentrate this would be of considerable economic benefit to the dairy industry. In the province of KwaZulu-Natal alone this could amount to as much as 20 million rand per annum.

Further work is required to test whether the differences observed in this trial also apply between other breeds of beef and dairy animals. Ideally a comparison between an early maturing dairy animal (such as the Jersey) and a large framed later maturing beef animal (the reverse of the current trial) would be recommended. The availability of herbage may have been limiting during the current trial due to the prevailing dry conditions. It would be usefull to conduct comparisons at differing levels of stocking intensity to determine whether the magnitude of differences decreases, or increases with increasing levels of herbage availability.

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**APPENDIX 1.** The sires of all heifers used in the trial and the heifers' initial ages, and weights

| Breed | Heifer number | Age (days) | Weight (kg) | Sire |
|---|---|---|---|---|
| Hereford | 8[1] | 446 | 200* | Hayhoe |
| | 16 | 445 | 225 | Apex |
| | 18 | 444 | 260 | Hayhoe |
| | 33 | 452 | 205 | Apex |
| | 36 | 446 | 307 | Apex |
| | 40 | 444 | 235 | Apex |
| | 61 | 415 | 195 | Hayhoe |
| | 66 | 405 | 205 | Apex |
| MEAN | | 437.13 | 229 | |
| S.E.M | | 6.06 | 13.53 | |
| Holstein | 19 | 399 | 280 | Astra |
| | 20 | 398 | 315 | Astra |
| | 21 | 397 | 280 | Astra |
| | 22 | 396 | 270 | Astra |
| | 23 | 394 | 295 | Astra |
| | 24 | 392 | 275 | Astra |
| | 25 | 392 | 275 | Astra |
| | 27 | 382 | 286 | Astra |
| MEAN | | 393.75 | 284.5 | |
| S.E.M | | 1.92 | 5.13 | |

[1] Heifer no. 8 entered trial two weeks late on 24 November 1995

## APPENDIX 2. Calibration of the disc meter

**Appendix 2A.** Disc-meter calibration data relating disc height (cm) to herbage dry matter (g) falling under the disc area (g) for fifty points in each camp

| | Camp : X51 | | Camp : BSS, BSN | | Camp : Y10 | | Camp : V10 | | Camp : X52 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Point | Disc Height (cm) | DM (g) | Disc Height (cm) | DM (g) | Disc Height (cm) | DM (g) | Disc Height (cm) | DM (g) | Disc Height (cm) | DM (g) |
| 1 | 6 | 36 | 10 | 55 | 11 | 76 | 19 | 117 | 16 | 67 |
| 2 | 15 | 86 | 18 | 80 | 9 | 73 | 6 | 46 | 2 | 20 |
| 3 | 12 | 68 | 19 | 98 | 11 | 94 | 6 | 55 | 16 | 117 |
| 4 | 15 | 77 | 9 | 61 | 10 | 86 | 13 | 80 | 13 | 85 |
| 5 | 15 | 84 | 7 | 41 | 3 | 35 | 10 | 71 | 4 | 29 |
| 6 | 9 | 53 | 14 | 87 | 10 | 91 | 7 | 69 | 15 | 71 |
| 7 | 12 | 56 | 23 | 158 | 2 | 23 | 8 | 53 | 10 | 49 |
| 8 | 8 | 58 | 5 | 36 | 1 | 24 | 16 | 119 | 10 | 50 |
| 9 | 3 | 24 | 16 | 171 | 14 | 86 | 13 | 80 | 18 | 140 |
| 10 | 7 | 36 | 18 | 119 | 4 | 77 | 4 | 34 | 8 | 47 |
| 11 | 15 | 80 | 7 | 19 | 10 | 84 | 7 | 44 | 6 | 29 |
| 12 | 7 | 49 | 8 | 50 | 14 | 106 | 25 | 109 | 13 | 61 |
| 13 | 14 | 71 | 9 | 38 | 17 | 81 | 6 | 37 | 7 | 45 |
| 14 | 7 | 49 | 7 | 37 | 4 | 57 | 13 | 87 | 13 | 44 |
| 15 | 9 | 50 | 18 | 70 | 9 | 46 | 8 | 35 | 8 | 28 |
| 16 | 8 | 36 | 18 | 100 | 11 | 106 | 20 | 141 | 15 | 100 |
| 17 | 10 | 45 | 11 | 55 | 10 | 68 | 14 | 90 | 18 | 117 |
| 18 | 5 | 28 | 17 | 70 | 13 | 66 | 23 | 135 | 13 | 91 |
| 19 | 8 | 39 | 17 | 81 | 10 | 92 | 24 | 131 | 15 | 74 |
| 20 | 14 | 81 | 5 | 39 | 16 | 80 | 22 | 80 | 12 | 74 |
| 21 | 3 | 17 | 20 | 93 | 5 | 71 | 19 | 73 | 8 | 44 |
| 22 | 12 | 59 | 13 | 65 | 15 | 74 | 20 | 127 | 16 | 71 |
| 23 | 3 | 29 | 3 | 23 | 2 | 36 | 17 | 74 | 5 | 20 |
| 24 | 11 | 73 | 23 | 245 | 7 | 46 | 13 | 61 | 12 | 70 |
| 25 | 7 | 53 | 21 | 86 | 14 | 76 | 18 | 101 | 21 | 95 |
| 26 | 13 | 91 | 4 | 44 | 7 | 51 | 16 | 81 | 4 | 20 |
| 27 | 11 | 55 | 25 | 110 | 6 | 79 | 5 | 29 | 14 | 70 |
| 28 | 8 | 47 | 13 | 93 | 6 | 60 | 22 | 179 | 9 | 60 |
| 29 | 8 | 42 | 5 | 51 | 9 | 89 | 7 | 46 | 17 | 70 |
| 30 | 4 | 39 | 6 | 52 | 11 | 125 | 17 | 87 | 18 | 101 |
| 31 | 15 | 124 | 19 | 99 | 10 | 76 | 7 | 34 | 8 | 40 |
| 32 | 10 | 54 | 5 | 59 | 4 | 50 | 25 | 88 | 9 | 40 |
| 33 | 3 | 38 | 13 | 87 | 4 | 62 | 14 | 95 | 15 | 62 |
| 34 | 1 | 14 | 10 | 87 | 4 | 94 | 11 | 64 | 9 | 53 |
| 35 | 2 | 25 | 11 | 77 | 15 | 123 | 14 | 96 | 11 | 44 |
| 36 | 2 | 15 | 2 | 25 | 12 | 80 | 4 | 36 | 17 | 84 |
| 37 | 6 | 30 | 10 | 72 | 7 | 59 | 10 | 99 | 12 | 66 |
| 38 | 2 | 40 | 6 | 75 | 11 | 79 | 11 | 55 | 9 | 50 |
| 39 | 5 | 48 | 4 | 46 | 2 | 22 | 3 | 13 | 14 | 53 |
| 40 | 6 | 20 | 8 | 84 | 10 | 75 | 10 | 80 | 7 | 25 |
| 41 | 9 | 69 | 10 | 71 | 5 | 51 | 18 | 125 | 11 | 61 |
| 42 | 18 | 75 | 12 | 63 | 19 | 111 | 11 | 90 | 15 | 64 |
| 43 | 13 | 80 | 14 | 60 | 9 | 59 | 9 | 37 | 5 | 35 |
| 44 | 5 | 27 | 13 | 70 | 15 | 83 | 3 | 24 | 9 | 35 |
| 45 | 12 | 50 | 13 | 59 | 7 | 55 | 9 | 52 | 17 | 116 |
| 46 | 10 | 78 | 5 | 54 | 18 | 157 | 11 | 66 | 16 | 92 |
| 47 | 4 | 45 | 11 | 73 | 16 | 94 | 6 | 69 | 8 | 42 |
| 48 | 8 | 87 | 19 | 115 | 2 | 43 | 10 | 76 | 18 | 84 |
| 49 | 10 | 39 | 5 | 51 | 11 | 80 | 10 | 82 | 13 | 69 |
| 50 | 5 | 44 | 12 | 72 | 8 | 91 | 10 | 84 | 25 | 92 |
| Mean | 8.5 | 52.26 | 11.82 | 74.52 | 9.2 | 74.04 | 12.48 | 76.72 | 12.08 | 63.32 |

**APPENDIX 2.** Calibration of the disc meter (cont...)

**Appendix 2B.** Results of regression analysis relating disc height (cm) to herbage dry matter (g) falling under the disc meter area

| Camp | Constant | X-coefficient | S.E. of coeff. | S.E. of Y | $r^2$ |
|---|---|---|---|---|---|
| BSS / BSN[1] | 16.93 | 4.87 | 0.63 | 26.30 | 0.55 |
| X51 | 14.02 | 4.50 | 0.44 | 13.22 | 0.68 |
| X52 | 4.13 | 4.90 | 0.46 | 15.48 | 0.70 |
| Y10 | 35.48 | 4.19 | 0.56 | 18.29 | 0.54 |
| V10 | 19.39 | 4.59 | 0.46 | 19.88 | 0.67 |

[1] BSN, and BSS were calibrated together due to them being one pasture periodically separated by an electric fence.

## APPENDIX 3. The use of the disc-meter to measure available herbage dry matter

### Appendix 3A. Recorded disc meter height readings, estimated available herbage dry matter ("IN" and "OUT"), and the estimated mean herbage dry matter consumed (kg/animal/day)

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 9/11/94 | | 24/11/94 | | 1/12/94 | | 8/12/94 | | | 13/12/94 | | 15/12/94 | | |
| Pasture no. | BSS | | X 51 | | X 52 | | BSS | | | BSS | | BSN | | |
| IN" or "OUT" | IN | | IN | | IN | | IN | | | OUT | | IN | | |
| Point | | | | | | | | | | | | | | |
| 1 | 9.00 | 5.00 | 4.00 | 7.00 | 2.00 | 7.00 | 4.00 | 3.00 | | 3.00 | 2.00 | 2.00 | 7.00 | |
| 2 | 5.00 | 10.00 | 3.00 | 9.00 | 3.00 | 7.00 | 3.00 | 4.00 | | 7.00 | 5.00 | 3.00 | 5.00 | |
| 3 | 7.00 | 8.00 | 6.00 | 7.00 | 3.00 | 6.00 | 4.00 | 5.00 | | 5.00 | 2.00 | 3.00 | 5.00 | |
| 4 | 6.00 | 8.00 | 7.00 | 10.00 | 5.00 | 6.00 | 8.00 | 5.00 | | 4.00 | 8.00 | 5.00 | 10.00 | |
| 5 | 6.00 | 10.00 | 5.00 | 8.00 | 5.00 | 4.00 | 5.00 | 3.00 | | 2.00 | 1.00 | 6.00 | 7.00 | |
| 6 | 8.00 | 8.00 | 4.00 | 6.00 | 4.00 | 7.00 | 3.00 | 6.00 | | 6.00 | 1.00 | 2.00 | 7.00 | |
| 7 | 10.00 | 5.00 | 4.00 | 7.00 | 7.00 | 6.00 | 2.00 | 5.00 | | 5.00 | 6.00 | 4.00 | 6.00 | |
| 8 | 9.00 | 8.00 | 4.00 | 7.00 | 6.00 | 7.00 | 5.00 | 5.00 | | 4.00 | 5.00 | 4.00 | 10.00 | |
| 9 | 11.00 | 10.00 | 4.00 | 8.00 | 7.00 | 5.00 | 3.00 | 8.00 | | 4.00 | 4.00 | 7.00 | 7.00 | |
| 10 | 11.00 | 7.00 | 6.00 | 7.00 | 5.00 | 5.00 | 5.00 | 6.00 | | 5.00 | 3.00 | 4.00 | 8.00 | |
| 11 | 8.00 | 4.00 | 6.00 | 6.00 | 4.00 | 4.00 | 5.00 | 8.00 | | 3.00 | 3.00 | 7.00 | 7.00 | |
| 12 | 11.00 | 6.00 | 8.00 | 4.00 | 6.00 | 6.00 | 3.00 | 4.00 | | 2.00 | 6.00 | 8.00 | 5.00 | |
| 13 | 15.00 | 3.00 | 6.00 | 7.00 | 4.00 | 5.00 | 5.00 | 7.00 | | 2.00 | 2.00 | 4.00 | 6.00 | |
| 14 | 8.00 | 7.00 | 5.00 | 7.00 | 6.00 | 4.00 | 2.00 | 12.00 | | 1.00 | 3.00 | 7.00 | 6.00 | |
| 15 | 12.00 | 4.00 | 4.00 | 3.00 | 5.00 | 6.00 | 1.00 | 11.00 | | 3.00 | 6.00 | 6.00 | 5.00 | |
| 16 | 10.00 | 3.00 | 6.00 | 7.00 | 4.00 | 5.00 | 7.00 | 9.00 | | 3.00 | 5.00 | 7.00 | 5.00 | |
| 17 | 11.00 | 8.00 | 4.00 | 5.00 | 3.00 | 5.00 | 4.00 | 7.00 | | 2.00 | 4.00 | 7.00 | 6.00 | |
| 18 | 14.00 | 6.00 | 4.00 | 9.00 | 5.00 | 2.00 | 4.00 | 8.00 | | 2.00 | 4.00 | 2.00 | 6.00 | |
| 19 | 9.00 | 4.00 | 3.00 | 8.00 | 4.00 | 6.00 | 4.00 | 11.00 | | 4.00 | 4.00 | 4.00 | 6.00 | |
| 20 | 11.00 | 8.00 | 5.00 | 5.00 | 2.00 | 6.00 | 3.00 | 8.00 | | 5.00 | 6.00 | 2.00 | 9.00 | |
| 21 | 8.00 | 9.00 | 4.00 | 2.00 | 3.00 | 2.00 | 9.00 | 9.00 | | 4.00 | 4.00 | 1.00 | 7.00 | |
| 22 | 12.00 | 6.00 | 6.00 | 6.00 | 5.00 | 1.00 | 6.00 | 9.00 | | 1.00 | 8.00 | 4.00 | 5.00 | |
| 23 | 11.00 | 5.00 | 5.00 | 4.00 | 5.00 | 1.00 | 3.00 | 8.00 | | 3.00 | 2.00 | 6.00 | 2.00 | |
| 24 | 7.00 | 8.00 | 5.00 | 6.00 | 5.00 | 3.00 | 3.00 | 16.00 | | 2.00 | 4.00 | 3.00 | 3.00 | |
| 25 | 12.00 | 8.00 | 6.00 | 5.00 | 4.00 | 3.00 | 3.00 | 5.00 | | 2.00 | 4.00 | 8.00 | 4.00 | |
| 26 | 10.00 | 7.00 | 7.00 | 4.00 | 7.00 | 5.00 | 6.00 | 6.00 | | 2.00 | 4.00 | 4.00 | 8.00 | |
| 27 | 8.00 | 6.00 | 10.00 | 3.00 | 6.00 | 3.00 | 4.00 | 3.00 | | 3.00 | 2.00 | 5.00 | 5.00 | |
| 28 | 9.00 | 11.00 | 9.00 | 6.00 | 5.00 | 4.00 | 2.00 | 9.00 | | 2.00 | 4.00 | 4.00 | 8.00 | |
| 29 | 4.00 | 8.00 | 8.00 | 7.00 | 5.00 | 4.00 | 2.00 | 14.00 | | 2.00 | 3.00 | 4.00 | 12.00 | |
| 30 | 4.00 | 10.00 | 6.00 | 4.00 | 2.00 | 5.00 | 7.00 | 10.00 | | 2.00 | 3.00 | 7.00 | 12.00 | |
| 31 | 8.00 | 11.00 | 8.00 | 6.00 | 6.00 | 6.00 | 4.00 | 6.00 | | 6.00 | 2.00 | 6.00 | 13.00 | |
| 32 | 2.00 | 8.00 | 7.00 | 9.00 | 3.00 | 6.00 | 6.00 | 7.00 | | 2.00 | 7.00 | 5.00 | 15.00 | |
| 33 | 5.00 | 4.00 | 8.00 | 6.00 | 2.00 | 6.00 | 2.00 | 6.00 | | 1.00 | 2.00 | 4.00 | 9.00 | |
| 34 | 2.00 | 9.00 | 9.00 | 5.00 | 4.00 | 6.00 | 6.00 | 12.00 | | 1.00 | 6.00 | 4.00 | 10.00 | |
| 35 | 5.00 | 11.00 | 6.00 | 7.00 | 2.00 | 6.00 | 5.00 | 6.00 | | 4.00 | 6.00 | 4.00 | 12.00 | |
| 36 | 6.00 | 10.00 | 10.00 | 7.00 | 4.00 | 5.00 | 3.00 | 12.00 | | 3.00 | 6.00 | 6.00 | 9.00 | |
| 37 | 6.00 | 10.00 | 9.00 | 5.00 | 6.00 | 4.00 | 6.00 | 6.00 | | 2.00 | 3.00 | 4.00 | 14.00 | |
| 38 | 7.00 | 7.00 | 9.00 | 7.00 | 3.00 | 4.00 | 7.00 | 8.00 | | 1.00 | 3.00 | 9.00 | 10.00 | |
| 39 | 8.00 | 2.00 | 6.00 | 11.00 | 8.00 | 4.00 | 7.00 | 7.00 | | 4.00 | 2.00 | 8.00 | 11.00 | |
| 40 | 15.00 | 8.00 | 7.00 | 6.00 | 7.00 | 6.00 | 7.00 | 8.00 | | 4.00 | 5.00 | 4.00 | 8.00 | |
| 41 | 7.00 | 11.00 | 7.00 | 7.00 | 4.00 | 2.00 | 2.00 | 9.00 | | 3.00 | 4.00 | 3.00 | 4.00 | |
| 42 | 6.00 | 8.00 | 9.00 | 7.00 | 4.00 | 1.00 | 5.00 | 14.00 | | 2.00 | 4.00 | 2.00 | 8.00 | |
| 43 | 7.00 | 14.00 | 8.00 | 4.00 | 6.00 | 1.00 | 5.00 | 5.00 | | 2.00 | 4.00 | 2.00 | 9.00 | |
| 44 | 7.00 | 10.00 | 10.00 | 9.00 | 4.00 | 2.00 | 3.00 | 5.00 | | 3.00 | 2.00 | 5.00 | 12.00 | |
| 45 | 7.00 | 12.00 | 6.00 | 5.00 | 9.00 | 2.00 | 5.00 | 4.00 | | 4.00 | 3.00 | 3.00 | 8.00 | |
| 46 | 5.00 | 9.00 | 8.00 | 4.00 | 7.00 | 3.00 | 5.00 | 7.00 | | 3.00 | 5.00 | 3.00 | 7.00 | |
| 47 | 6.00 | 8.00 | 8.00 | 6.00 | 2.00 | 3.00 | 5.00 | 8.00 | | 2.00 | 2.00 | 4.00 | 7.00 | |
| 48 | 8.00 | 13.00 | 10.00 | 5.00 | 3.00 | 2.00 | 4.00 | 7.00 | | 2.00 | 1.00 | 3.00 | 9.00 | |
| 49 | 9.00 | 10.00 | 5.00 | 5.00 | 2.00 | 3.00 | 6.00 | 15.00 | | 2.00 | 5.00 | 3.00 | 16.00 | |
| 50 | 3.00 | 8.00 | 9.00 | 5.00 | 7.00 | 3.00 | 6.00 | 8.00 | | 2.00 | 4.00 | 3.00 | 10.00 | |
| Total height (cm) | 405.00 | 393.00 | 321.00 | 310.00 | 230.00 | 215.00 | 224.00 | 384.00 | | 148.00 | 194.00 | 225.00 | 400.00 | |
| Mean height (cm) | 7.98 | | 6.31 | | 4.45 | | 6.08 | | | 3.42 | | 6.25 | | |
| Total kg's DM (In) | 1629.12 | | 1237.89 | | 756.99 | | 1358.88 | | | | | 1383.06 | | |
| Total kg's DM (out) | | | | | | | | | | 980.54 | | | | |
| DM consumed (kg's) | | | | | | | | | 378.34 | | | | | 529.11 |
| DM consumed (kg/ animal/ day) | | | | | | | | | 4.73 | | | | | 6.61 |

*** - camps grazed simultaneously

# - estimates of DMI lower than zero impossible, and therefore set to zero

## APPENDIX 3. The use of the disc-meter to measure available herbage dry matter (cont...)

**Appendix 3A.** Recorded disc meter height readings, estimated available herbage dry matter ("IN", and "OUT"), and the estimated mean herbage dry matter consumed (kg/animal/day) (cont...)

| 20/12/94<br>BSN<br>OUT | | 22/12/94<br>X 51<br>IN | | 29/12/94<br>X 52<br>IN | | 3/1/95<br>X 52<br>OUT | | 5/1/95<br>BSS<br>IN | | 12/1/95<br>BSS<br>OUT | | 12/1/95<br>BSN<br>IN | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 3.00 | 1.00 | 3.00 | 1.00 | 5.00 | 4.00 | 4.00 | 7.00 | 5.00 | 5.00 | 8.00 | 8.00 | 9.00 |
| 1.00 | 2.00 | 1.00 | 4.00 | 0.00 | 7.00 | 1.00 | 3.00 | 10.00 | 15.00 | 6.00 | 7.00 | 9.00 | 7.00 |
| 1.00 | 1.00 | 1.00 | 4.00 | 5.00 | 6.00 | 2.00 | 1.00 | 12.00 | 7.00 | 8.00 | 6.00 | 5.00 | 6.00 |
| 0.00 | 1.00 | 2.00 | 5.00 | 1.00 | 5.00 | 3.00 | 4.00 | 10.00 | 8.00 | 12.00 | 5.00 | 8.00 | 4.00 |
| 1.00 | 0.00 | 4.00 | 2.00 | 0.00 | 7.00 | 2.00 | 5.00 | 13.00 | 8.00 | 11.00 | 4.00 | 8.00 | 4.00 |
| 2.00 | 1.00 | 2.00 | 5.00 | 1.00 | 6.00 | 5.00 | 1.00 | 6.00 | 13.00 | 7.00 | 8.00 | 7.00 | 7.00 |
| 1.00 | 2.00 | 4.00 | 4.00 | 3.00 | 5.00 | 7.00 | 2.00 | 9.00 | 11.00 | 10.00 | 7.00 | 8.00 | 4.00 |
| 3.00 | 1.00 | 3.00 | 6.00 | 7.00 | 1.00 | 5.00 | 0.00 | 10.00 | 15.00 | 9.00 | 6.00 | 8.00 | 7.00 |
| 5.00 | 0.00 | 2.00 | 4.00 | 5.00 | 5.00 | 4.00 | 1.00 | 7.00 | 10.00 | 11.00 | 3.00 | 10.00 | 4.00 |
| 1.00 | 1.00 | 5.00 | 4.00 | 3.00 | 6.00 | 3.00 | 3.00 | 9.00 | 12.00 | 7.00 | 9.00 | 6.00 | 7.00 |
| 1.00 | 0.00 | 2.00 | 7.00 | 0.00 | 3.00 | 3.00 | 4.00 | 12.00 | 9.00 | 6.00 | 10.00 | 10.00 | 8.00 |
| 3.00 | 3.00 | 2.00 | 7.00 | 0.00 | 4.00 | 2.00 | 2.00 | 6.00 | 8.00 | 5.00 | 4.00 | 12.00 | 7.00 |
| 1.00 | 2.00 | 3.00 | 5.00 | 5.00 | 1.00 | 5.00 | 4.00 | 4.00 | 7.00 | 7.00 | 6.00 | 8.00 | 7.00 |
| 0.00 | 1.00 | 5.00 | 4.00 | 3.00 | 3.00 | 4.00 | 4.00 | 10.00 | 14.00 | 8.00 | 7.00 | 5.00 | 6.00 |
| 1.00 | 7.00 | 6.00 | 4.00 | 7.00 | 1.00 | 3.00 | 4.00 | 9.00 | 12.00 | 10.00 | 5.00 | 6.00 | 4.00 |
| 1.00 | 9.00 | 5.00 | 4.00 | 5.00 | 3.00 | 3.00 | 5.00 | 13.00 | 12.00 | 7.00 | 7.00 | 8.00 | 11.00 |
| 0.00 | 6.00 | 5.00 | 5.00 | 4.00 | 6.00 | 3.00 | 6.00 | 10.00 | 17.00 | 13.00 | 4.00 | 5.00 | 6.00 |
| 0.00 | 3.00 | 4.00 | 4.00 | 1.00 | 4.00 | 2.00 | 3.00 | 11.00 | 8.00 | 10.00 | 6.00 | 4.00 | 7.00 |
| 2.00 | 0.00 | 4.00 | 2.00 | 0.00 | 3.00 | 2.00 | 4.00 | 14.00 | 18.00 | 6.00 | 3.00 | 5.00 | 7.00 |
| 0.00 | 4.00 | 3.00 | 4.00 | 1.00 | 1.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 | 3.00 | 4.00 | 6.00 |
| 1.00 | 1.00 | 3.00 | 3.00 | 3.00 | 3.00 | 4.00 | 5.00 | 6.00 | 18.00 | 3.00 | 4.00 | 9.00 | 3.00 |
| 2.00 | 3.00 | 4.00 | 4.00 | 0.00 | 0.00 | 4.00 | 6.00 | 12.00 | 7.00 | 6.00 | 7.00 | 11.00 | 4.00 |
| 4.00 | 6.00 | 1.00 | 2.00 | 1.00 | 1.00 | 2.00 | 4.00 | 9.00 | 9.00 | 3.00 | 8.00 | 10.00 | 6.00 |
| 1.00 | 9.00 | 2.00 | 2.00 | 1.00 | 3.00 | 1.00 | 5.00 | 8.00 | 15.00 | 5.00 | 8.00 | 5.00 | 11.00 |
| 3.00 | 7.00 | 3.00 | 3.00 | 3.00 | 6.00 | 4.00 | 3.00 | 8.00 | 19.00 | 10.00 | 6.00 | 7.00 | 6.00 |
| 4.00 | 8.00 | 0.00 | 3.00 | 3.00 | 5.00 | 4.00 | 2.00 | 6.00 | 13.00 | 6.00 | 3.00 | 8.00 | 10.00 |
| 1.00 | 7.00 | 3.00 | 3.00 | 2.00 | 1.00 | 5.00 | 3.00 | 9.00 | 11.00 | 7.00 | 8.00 | 4.00 | 10.00 |
| 0.00 | 9.00 | 5.00 | 4.00 | 0.00 | 3.00 | 6.00 | 6.00 | 4.00 | 14.00 | 5.00 | 3.00 | 2.00 | 14.00 |
| 1.00 | 4.00 | 6.00 | 4.00 | 1.00 | 3.00 | 5.00 | 2.00 | 5.00 | 14.00 | 4.00 | 5.00 | 12.00 | 4.00 |
| 2.00 | 6.00 | 1.00 | 4.00 | 1.00 | 4.00 | 4.00 | 4.00 | 8.00 | 16.00 | 9.00 | 6.00 | 11.00 | 8.00 |
| 3.00 | 3.00 | 6.00 | 7.00 | 3.00 | 3.00 | 5.00 | 0.00 | 7.00 | 14.00 | 12.00 | 9.00 | 11.00 | 15.00 |
| 1.00 | 2.00 | 3.00 | 3.00 | 6.00 | 1.00 | 3.00 | 6.00 | 1.00 | 17.00 | 6.00 | 7.00 | 8.00 | 6.00 |
| 0.00 | 4.00 | 6.00 | 2.00 | 3.00 | 3.00 | 4.00 | 1.00 | 5.00 | 12.00 | 9.00 | 8.00 | 2.00 | 13.00 |
| 0.00 | 5.00 | 3.00 | 3.00 | 2.00 | 6.00 | 7.00 | 2.00 | 11.00 | 17.00 | 7.00 | 5.00 | 4.00 | 15.00 |
| 1.00 | 4.00 | 5.00 | 4.00 | 5.00 | 1.00 | 4.00 | 0.00 | 6.00 | 10.00 | 4.00 | 6.00 | 3.00 | 11.00 |
| 0.00 | 1.00 | 5.00 | 6.00 | 6.00 | 5.00 | 5.00 | 4.00 | 10.00 | 11.00 | 8.00 | 8.00 | 5.00 | 14.00 |
| 1.00 | 3.00 | 3.00 | 3.00 | 0.00 | 1.00 | 4.00 | 0.00 | 4.00 | 12.00 | 5.00 | 6.00 | 7.00 | 7.00 |
| 0.00 | 6.00 | 4.00 | 6.00 | 4.00 | 3.00 | 3.00 | 1.00 | 9.00 | 9.00 | 4.00 | 4.00 | 3.00 | 6.00 |
| 1.00 | 3.00 | 5.00 | 3.00 | 6.00 | 6.00 | 6.00 | 4.00 | 9.00 | 5.00 | 8.00 | 5.00 | 2.00 | 10.00 |
| 1.00 | 2.00 | 7.00 | 6.00 | 5.00 | 0.00 | 7.00 | 1.00 | 6.00 | 6.00 | 8.00 | 8.00 | 10.00 | 8.00 |
| 2.00 | 5.00 | 5.00 | 3.00 | 3.00 | 0.00 | 5.00 | 2.00 | 7.00 | 8.00 | 7.00 | 4.00 | 1.00 | 7.00 |
| 1.00 | 7.00 | 7.00 | 8.00 | 5.00 | 1.00 | 1.00 | 0.00 | 5.00 | 8.00 | 4.00 | 6.00 | 2.00 | 3.00 |
| 2.00 | 3.00 | 3.00 | 4.00 | 2.00 | 3.00 | 1.00 | 1.00 | 6.00 | 4.00 | 5.00 | 4.00 | 5.00 | 5.00 |
| 1.00 | 4.00 | 3.00 | 7.00 | 1.00 | 2.00 | 1.00 | 4.00 | 4.00 | 9.00 | 3.00 | 4.00 | 4.00 | 10.00 |
| 3.00 | 7.00 | 6.00 | 7.00 | 3.00 | 0.00 | 2.00 | 1.00 | 10.00 | 17.00 | 5.00 | 6.00 | 2.00 | 7.00 |
| 1.00 | 3.00 | 7.00 | 7.00 | 5.00 | 4.00 | 4.00 | 2.00 | 14.00 | 10.00 | 7.00 | 4.00 | 3.00 | 6.00 |
| 1.00 | 6.00 | 4.00 | 7.00 | 6.00 | 1.00 | 4.00 | 3.00 | 12.00 | 8.00 | 3.00 | 4.00 | 2.00 | 9.00 |
| 2.00 | 5.00 | 5.00 | 5.00 | 1.00 | 3.00 | 1.00 | 1.00 | 8.00 | 9.00 | 2.00 | 5.00 | 6.00 | 7.00 |
| 1.00 | 3.00 | 5.00 | 4.00 | 3.00 | 2.00 | 3.00 | 0.00 | 10.00 | 4.00 | 4.00 | 6.00 | 3.00 | 5.00 |
| 1.00 | 4.00 | 4.00 | 4.00 | 4.00 | 3.00 | 2.00 | 3.00 | 7.00 | 8.00 | 5.00 | 6.00 | 10.00 | 7.00 |
| | | | | | | | | | | | | | |
| 66.00 | 187.00 | 188.00 | 218.00 | 140.00 | 159.00 | 180.00 | 143.00 | 416.00 | 552.00 | 342.00 | 291.00 | 315.00 | 375.00 |
| 2.53 | | 4.06 | | 2.99 | | 3.23 | | 9.68 | | 6.33 | | 6.90 | |
| 853.95 | | 942.39 | | 548.15 | | 582.48 | | 1870.92 | | 1394.44 | | 1475.51 | |
| | | | | | | 0# | | | | 476.48 | | | 393.99 |
| | | | | | | 0# | | | | 4.25 | | | 3.52 |

# **APPENDIX 3.** The use of the disc-meter to measure available herbage dry matter (cont...)

**Appendix 3A.** Recorded disc meter height readings, estimated available herbage dry matter ("IN", and "OUT"), and the estimated mean herbage DM consumed (kg/animal/day) (cont...)

| 19/1/95 | | 19/1/95 | | 26/1/95 | | | 2/2/95 | | | 2/2/95 | | 9/2/95 | | 6/2/95 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BSN | | Y 10 | | V 10 | | | V 10 | | | X 51*** | | X 51*** | | X 52*** | |
| OUT | | IN | | IN | | | OUT | | | IN | | OUT | | IN | |
| 7.00 | 1.00 | 16.00 | 2.00 | 5.00 | 4.00 | 10.00 | 1.00 | 11.00 | 3.00 | 16.00 | 8.00 | 2.00 | 7.00 | 6.00 | 7.00 |
| 9.00 | 4.00 | 12.00 | 3.00 | 3.00 | 4.00 | 9.00 | 2.00 | 6.00 | 8.00 | 9.00 | 7.00 | 7.00 | 5.00 | 6.00 | 7.00 |
| 4.00 | 9.00 | 11.00 | 6.00 | 12.00 | 8.00 | 3.00 | 10.00 | 8.00 | 4.00 | 15.00 | 8.00 | 9.00 | 6.00 | 4.00 | 8.00 |
| 7.00 | 4.00 | 14.00 | 11.00 | 12.00 | 7.00 | 10.00 | 2.00 | 8.00 | 3.00 | 15.00 | 6.00 | 8.00 | 9.00 | 5.00 | 9.00 |
| 8.00 | 6.00 | 16.00 | 14.00 | 11.00 | 11.00 | 4.00 | 7.00 | 2.00 | 6.00 | 12.00 | 10.00 | 6.00 | 7.00 | 5.00 | 10.00 |
| 5.00 | 4.00 | 12.00 | 18.00 | 12.00 | 6.00 | 8.00 | 8.00 | 8.00 | 10.00 | 16.00 | 10.00 | 11.00 | 11.00 | 9.00 | 7.00 |
| 6.00 | 2.00 | 9.00 | 17.00 | 10.00 | 7.00 | 14.00 | 8.00 | 3.00 | 4.00 | 15.00 | 8.00 | 5.00 | 9.00 | 8.00 | 10.00 |
| 5.00 | 6.00 | 7.00 | 20.00 | 8.00 | 5.00 | 7.00 | 6.00 | 3.00 | 8.00 | 10.00 | 26.00 | 3.00 | 14.00 | 8.00 | 11.00 |
| 5.00 | 5.00 | 9.00 | 19.00 | 11.00 | 12.00 | 5.00 | 3.00 | 4.00 | 8.00 | 12.00 | 15.00 | 7.00 | 6.00 | 7.00 | 9.00 |
| 6.00 | 4.00 | 6.00 | 11.00 | 14.00 | 10.00 | 4.00 | 4.00 | 9.00 | 4.00 | 15.00 | 13.00 | 5.00 | 5.00 | 7.00 | 7.00 |
| 4.00 | 3.00 | 8.00 | 12.00 | 13.00 | 6.00 | 5.00 | 4.00 | 0.00 | 3.00 | 15.00 | 9.00 | 9.00 | 7.00 | 6.00 | 6.00 |
| 3.00 | 5.00 | 7.00 | 13.00 | 14.00 | 8.00 | 6.00 | 5.00 | 6.00 | 0.00 | 9.00 | 10.00 | 6.00 | 4.00 | 6.00 | 7.00 |
| 5.00 | 4.00 | 6.00 | 7.00 | 11.00 | 10.00 | 3.00 | 5.00 | 6.00 | 6.00 | 12.00 | 11.00 | 4.00 | 3.00 | 11.00 | 6.00 |
| 2.00 | 4.00 | 7.00 | 9.00 | 9.00 | 7.00 | 3.00 | 4.00 | 1.00 | 8.00 | 7.00 | 14.00 | 7.00 | 1.00 | 5.00 | 4.00 |
| 1.00 | 0.00 | 14.00 | 19.00 | 6.00 | 5.00 | 6.00 | 4.00 | 8.00 | 5.00 | 8.00 | 11.00 | 4.00 | 0.00 | 9.00 | 7.00 |
| 0.00 | 2.00 | 10.00 | 18.00 | 11.00 | 11.00 | 6.00 | 5.00 | 2.00 | 5.00 | 11.00 | 12.00 | 3.00 | 3.00 | 5.00 | 7.00 |
| 0.00 | 5.00 | 13.00 | 16.00 | 8.00 | 8.00 | 7.00 | 3.00 | 5.00 | 5.00 | 8.00 | 10.00 | 2.00 | 7.00 | 5.00 | 13.00 |
| 1.00 | 11.00 | 16.00 | 13.00 | 13.00 | 11.00 | 10.00 | 4.00 | 7.00 | 4.00 | 8.00 | 10.00 | 1.00 | 5.00 | 7.00 | 13.00 |
| 5.00 | 9.00 | 16.00 | 10.00 | 5.00 | 8.00 | 11.00 | 3.00 | 8.00 | 7.00 | 12.00 | 11.00 | 2.00 | 7.00 | 8.00 | 9.00 |
| 2.00 | 6.00 | 14.00 | 7.00 | 8.00 | 9.00 | 8.00 | 13.00 | 9.00 | 5.00 | 11.00 | 13.00 | 0.00 | 11.00 | 6.00 | 8.00 |
| 6.00 | 7.00 | 10.00 | 12.00 | 3.00 | 8.00 | 7.00 | 5.00 | 7.00 | 7.00 | 12.00 | 7.00 | 1.00 | 9.00 | 4.00 | 5.00 |
| 3.00 | 3.00 | 16.00 | 12.00 | 4.00 | 7.00 | 11.00 | 6.00 | 3.00 | 5.00 | 9.00 | 8.00 | 3.00 | 6.00 | 7.00 | 2.00 |
| 7.00 | 6.00 | 10.00 | 19.00 | 6.00 | 3.00 | 8.00 | 5.00 | 4.00 | 9.00 | 12.00 | 10.00 | 5.00 | 4.00 | 12.00 | 5.00 |
| 5.00 | 4.00 | 15.00 | 20.00 | 14.00 | 6.00 | 4.00 | 4.00 | 5.00 | 15.00 | 12.00 | 14.00 | 11.00 | 8.00 | 11.00 | 5.00 |
| 2.00 | 2.00 | 11.00 | 15.00 | 15.00 | 12.00 | 6.00 | 4.00 | 4.00 | 7.00 | 10.00 | 17.00 | 7.00 | 7.00 | 2.00 | 6.00 |
| 6.00 | 7.00 | 12.00 | 8.00 | 7.00 | 15.00 | 3.00 | 1.00 | 2.00 | 5.00 | 6.00 | 15.00 | 9.00 | 6.00 | 5.00 | 8.00 |
| 2.00 | 7.00 | 10.00 | 16.00 | 8.00 | 17.00 | 4.00 | 5.00 | 3.00 | 9.00 | 15.00 | 9.00 | 7.00 | 5.00 | 5.00 | 6.00 |
| 1.00 | 6.00 | 16.00 | 14.00 | 5.00 | 8.00 | 6.00 | 10.00 | 3.00 | 4.00 | 10.00 | 11.00 | 4.00 | 9.00 | 2.00 | 7.00 |
| 8.00 | 4.00 | 14.00 | 21.00 | 3.00 | 10.00 | 3.00 | 5.00 | 4.00 | 12.00 | 6.00 | 7.00 | 6.00 | 11.00 | 5.00 | 7.00 |
| 7.00 | 9.00 | 15.00 | 19.00 | 4.00 | 16.00 | 6.00 | 6.00 | 9.00 | 8.00 | 6.00 | 21.00 | 9.00 | 6.00 | 13.00 | 9.00 |
| 7.00 | 7.00 | 14.00 | 11.00 | 4.00 | 6.00 | 9.00 | 6.00 | 7.00 | 10.00 | 4.00 | 19.00 | 11.00 | 5.00 | 9.00 | 6.00 |
| 1.00 | 9.00 | 18.00 | 6.00 | 6.00 | 13.00 | 3.00 | 3.00 | 4.00 | 4.00 | 8.00 | 8.00 | 6.00 | 11.00 | 5.00 | 9.00 |
| 1.00 | 5.00 | 16.00 | 7.00 | 5.00 | 13.00 | 12.00 | 6.00 | 7.00 | 8.00 | 13.00 | 14.00 | 7.00 | 7.00 | 6.00 | 5.00 |
| 2.00 | 6.00 | 17.00 | 9.00 | 5.00 | 20.00 | 15.00 | 4.00 | 4.00 | 10.00 | 5.00 | 15.00 | 11.00 | 11.00 | 2.00 | 10.00 |
| 0.00 | 4.00 | 13.00 | 6.00 | 10.00 | 14.00 | 17.00 | 6.00 | 4.00 | 6.00 | 9.00 | 11.00 | 13.00 | 9.00 | 2.00 | 9.00 |
| 0.00 | 3.00 | 12.00 | 6.00 | 5.00 | 18.00 | 3.00 | 6.00 | 2.00 | 11.00 | 5.00 | 12.00 | 7.00 | 11.00 | 4.00 | 8.00 |
| 1.00 | 5.00 | 10.00 | 4.00 | 11.00 | 9.00 | 10.00 | 5.00 | 4.00 | 10.00 | 7.00 | 7.00 | 11.00 | 9.00 | 2.00 | 10.00 |
| 0.00 | 6.00 | 12.00 | 13.00 | 4.00 | 11.00 | 5.00 | 2.00 | 5.00 | 10.00 | 7.00 | 10.00 | 6.00 | 8.00 | 4.00 | 10.00 |
| 0.00 | 7.00 | 13.00 | 16.00 | 7.00 | 13.00 | 11.00 | 4.00 | 3.00 | 4.00 | 6.00 | 12.00 | 4.00 | 7.00 | 4.00 | 8.00 |
| 1.00 | 8.00 | 14.00 | 15.00 | 8.00 | 13.00 | 7.00 | 8.00 | 2.00 | 8.00 | 9.00 | 15.00 | 3.00 | 9.00 | 6.00 | 6.00 |
| 2.00 | 5.00 | 11.00 | 18.00 | 5.00 | 11.00 | 10.00 | 6.00 | 3.00 | 4.00 | 4.00 | 10.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| 1.00 | 9.00 | 8.00 | 21.00 | 4.00 | 9.00 | 5.00 | 11.00 | 7.00 | 12.00 | 6.00 | 7.00 | 9.00 | 6.00 | 4.00 | 2.00 |
| 2.00 | 5.00 | 12.00 | 19.00 | 9.00 | 5.00 | 11.00 | 7.00 | 8.00 | 5.00 | 3.00 | 7.00 | 11.00 | 5.00 | 3.00 | 4.00 |
| 1.00 | 4.00 | 10.00 | 13.00 | 6.00 | 10.00 | 6.00 | 8.00 | 5.00 | 5.00 | 4.00 | 7.00 | 13.00 | 4.00 | 7.00 | 7.00 |
| 1.00 | 3.00 | 4.00 | 10.00 | 9.00 | 6.00 | 8.00 | 11.00 | 11.00 | 14.00 | 13.00 | 10.00 | 3.00 | 7.00 | 2.00 | 9.00 |
| 1.00 | 3.00 | 6.00 | 8.00 | 5.00 | 7.00 | 10.00 | 4.00 | 5.00 | 5.00 | 1.00 | 5.00 | 7.00 | 5.00 | 4.00 | 7.00 |
| 1.00 | 4.00 | 11.00 | 4.00 | 7.00 | 6.00 | 7.00 | 6.00 | 7.00 | 10.00 | 5.00 | 5.00 | 9.00 | 4.00 | 4.00 | 8.00 |
| 2.00 | 5.00 | 7.00 | 10.00 | 4.00 | 6.00 | 4.00 | 4.00 | 16.00 | 7.00 | 11.00 | 9.00 | 11.00 | 2.00 | 5.00 | 8.00 |
| 1.00 | 5.00 | 15.00 | 13.00 | 3.00 | 4.00 | 7.00 | 6.00 | 7.00 | 9.00 | 6.00 | 8.00 | 6.00 | 6.00 | 6.00 | 7.00 |
| 1.00 | 3.00 | 6.00 | 8.00 | 6.00 | 11.00 | 7.00 | 6.00 | 5.00 | 9.00 | 11.00 | 8.00 | 9.00 | 7.00 | 6.00 | 3.00 |
| 158.00 | 255.00 | 581.00 | 618.00 | 388.00 | 464.00 | 363.00 | 271.00 | 274.00 | 348.00 | 471.00 | 540.00 | 327.00 | 338.00 | 291.00 | 368.00 |
| 4.13 | | 11.99 | | 8.10 | | | 5.95 | | | 10.11 | | 6.65 | | 6.59 | |
| | | 2502.66 | | 1652.23 | | | | | | 1736.96 | | | | 1063.09 | |
| 1081.53 | | | | | | | 1364.40 | | | | | 1282.54 | | | |
| | | | | | | 287.83 | | | | | 454.42 | | | | 0# |
| | | | | | | 2.57 | | | | | 4.06 | | | | |

**APPENDIX 3.** The use of the disc-meter to measure available herbage dry matter (cont...)

**Appendix 3A.** Recorded disc meter height readings, estimated available herbage dry matter ("IN", and "OUT"), and the estimated mean herbage dry matter consumed (kg/animal/day) (cont...)

| 9/2/95 | | 9/2/95 | | 16/2/95 | | 16/2/95 | | 23/2/95 | | 23/2/95 | | 28/2/95 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X 52*** | | BSS | | BSS | | BSN | | BSN | | Y 10 | | Y 10 | |
| OUT | | IN | | OUT | | IN | | OUT | | IN | | OUT | |
| 6.00 | 8.00 | 20.00 | 16.00 | 8.00 | 6.00 | 10.00 | 3.00 | 4.00 | 4.00 | 1.00 | 17.00 | 2.00 | 1.00 |
| 2.00 | 9.00 | 19.00 | 20.00 | 11.00 | 7.00 | 12.00 | 6.00 | 4.00 | 3.00 | 3.00 | 6.00 | 2.00 | 1.00 |
| 3.00 | 11.00 | 12.00 | 19.00 | 6.00 | 10.00 | 16.00 | 2.00 | 5.00 | 8.00 | 1.00 | 5.00 | 7.00 | 2.00 |
| 5.00 | 5.00 | 11.00 | 12.00 | 13.00 | 11.00 | 8.00 | 8.00 | 7.00 | 1.00 | 3.00 | 9.00 | 8.00 | 4.00 |
| 7.00 | 11.00 | 10.00 | 24.00 | 10.00 | 7.00 | 13.00 | 6.00 | 2.00 | 4.00 | 1.00 | 11.00 | 4.00 | 8.00 |
| 9.00 | 8.00 | 12.00 | 18.00 | 14.00 | 7.00 | 11.00 | 10.00 | 6.00 | 3.00 | 1.00 | 6.00 | 3.00 | 2.00 |
| 11.00 | 11.00 | 11.00 | 21.00 | 14.00 | 7.00 | 12.00 | 4.00 | 9.00 | 1.00 | 5.00 | 7.00 | 7.00 | 5.00 |
| 6.00 | 13.00 | 9.00 | 12.00 | 8.00 | 9.00 | 12.00 | 6.00 | 1.00 | 2.00 | 3.00 | 9.00 | 4.00 | 6.00 |
| 5.00 | 6.00 | 13.00 | 21.00 | 10.00 | 7.00 | 6.00 | 2.00 | 5.00 | 6.00 | 6.00 | 6.00 | 8.00 | 3.00 |
| 9.00 | 4.00 | 12.00 | 24.00 | 7.00 | 3.00 | 10.00 | 6.00 | 4.00 | 9.00 | 5.00 | 11.00 | 8.00 | 5.00 |
| 6.00 | 5.00 | 11.00 | 20.00 | 6.00 | 1.00 | 4.00 | 7.00 | 2.00 | 10.00 | 7.00 | 6.00 | 8.00 | 4.00 |
| 13.00 | 3.00 | 11.00 | 18.00 | 11.00 | 7.00 | 4.00 | 6.00 | 4.00 | 4.00 | 3.00 | 7.00 | 3.00 | 4.00 |
| 9.00 | 13.00 | 17.00 | 18.00 | 10.00 | 5.00 | 11.00 | 5.00 | 0.00 | 1.00 | 9.00 | 9.00 | 4.00 | 3.00 |
| 8.00 | 8.00 | 10.00 | 22.00 | 12.00 | 4.00 | 12.00 | 8.00 | 5.00 | 2.00 | 7.00 | 7.00 | 9.00 | 6.00 |
| 7.00 | 6.00 | 21.00 | 18.00 | 5.00 | 5.00 | 7.00 | 12.00 | 3.00 | 6.00 | 6.00 | 5.00 | 2.00 | 6.00 |
| 6.00 | 9.00 | 9.00 | 24.00 | 7.00 | 4.00 | 9.00 | 13.00 | 6.00 | 4.00 | 5.00 | 6.00 | 5.00 | 3.00 |
| 4.00 | 11.00 | 12.00 | 19.00 | 5.00 | 7.00 | 6.00 | 4.00 | 5.00 | 4.00 | 6.00 | 8.00 | 7.00 | 4.00 |
| 6.00 | 9.00 | 17.00 | 17.00 | 7.00 | 8.00 | 6.00 | 10.00 | 9.00 | 3.00 | 4.00 | 7.00 | 6.00 | 4.00 |
| 5.00 | 6.00 | 11.00 | 24.00 | 6.00 | 5.00 | 5.00 | 10.00 | 6.00 | 4.00 | 7.00 | 6.00 | 6.00 | 1.00 |
| 7.00 | 11.00 | 8.00 | 34.00 | 4.00 | 8.00 | 3.00 | 10.00 | 10.00 | 8.00 | 7.00 | 5.00 | 6.00 | 5.00 |
| 9.00 | 7.00 | 18.00 | 24.00 | 4.00 | 6.00 | 2.00 | 2.00 | 5.00 | 7.00 | 11.00 | 8.00 | 4.00 | 7.00 |
| 5.00 | 9.00 | 12.00 | 34.00 | 8.00 | 4.00 | 4.00 | 7.00 | 3.00 | 7.00 | 11.00 | 9.00 | 4.00 | 7.00 |
| 9.00 | 8.00 | 18.00 | 14.00 | 7.00 | 7.00 | 6.00 | 6.00 | 4.00 | 4.00 | 13.00 | 6.00 | 3.00 | 6.00 |
| 3.00 | 7.00 | 14.00 | 14.00 | 10.00 | 3.00 | 13.00 | 11.00 | 1.00 | 2.00 | 9.00 | 5.00 | 3.00 | 5.00 |
| 7.00 | 9.00 | 10.00 | 27.00 | 12.00 | 6.00 | 8.00 | 6.00 | 1.00 | 8.00 | 6.00 | 11.00 | 5.00 | 7.00 |
| 5.00 | 11.00 | 16.00 | 29.00 | 8.00 | 8.00 | 11.00 | 10.00 | 6.00 | 6.00 | 7.00 | 10.00 | 5.00 | 10.00 |
| 9.00 | 6.00 | 14.00 | 26.00 | 6.00 | 4.00 | 8.00 | 7.00 | 4.00 | 8.00 | 5.00 | 9.00 | 9.00 | 10.00 |
| 1.00 | 5.00 | 14.00 | 16.00 | 7.00 | 5.00 | 9.00 | 11.00 | 3.00 | 10.00 | 4.00 | 6.00 | 8.00 | 6.00 |
| 7.00 | 7.00 | 8.00 | 29.00 | 6.00 | 10.00 | 6.00 | 9.00 | 2.00 | 11.00 | 6.00 | 5.00 | 3.00 | 3.00 |
| 14.00 | 9.00 | 12.00 | 32.00 | 6.00 | 4.00 | 5.00 | 11.00 | 3.00 | 8.00 | 2.00 | 7.00 | 1.00 | 5.00 |
| 9.00 | 6.00 | 11.00 | 24.00 | 5.00 | 7.00 | 2.00 | 13.00 | 1.00 | 1.00 | 1.00 | 11.00 | 4.00 | 4.00 |
| 11.00 | 3.00 | 8.00 | 27.00 | 9.00 | 1.00 | 8.00 | 10.00 | 4.00 | 13.00 | 1.00 | 9.00 | 2.00 | 1.00 |
| 11.00 | 7.00 | 14.00 | 19.00 | 8.00 | 3.00 | 11.00 | 15.00 | 3.00 | 8.00 | 0.00 | 11.00 | 7.00 | 2.00 |
| 5.00 | 8.00 | 19.00 | 27.00 | 2.00 | 3.00 | 7.00 | 12.00 | 0.00 | 12.00 | 1.00 | 7.00 | 7.00 | 7.00 |
| 4.00 | 9.00 | 9.00 | 22.00 | 3.00 | 7.00 | 2.00 | 11.00 | 8.00 | 5.00 | 3.00 | 9.00 | 5.00 | 3.00 |
| 3.00 | 6.00 | 8.00 | 20.00 | 7.00 | 4.00 | 7.00 | 14.00 | 3.00 | 6.00 | 5.00 | 11.00 | 2.00 | 5.00 |
| 8.00 | 5.00 | 8.00 | 12.00 | 5.00 | 1.00 | 2.00 | 15.00 | 4.00 | 14.00 | 9.00 | 13.00 | 2.00 | 4.00 |
| 7.00 | 3.00 | 16.00 | 26.00 | 12.00 | 4.00 | 2.00 | 13.00 | 10.00 | 9.00 | 9.00 | 5.00 | 3.00 | 8.00 |
| 9.00 | 9.00 | 15.00 | 23.00 | 7.00 | 3.00 | 4.00 | 16.00 | 6.00 | 12.00 | 13.00 | 7.00 | 1.00 | 8.00 |
| 10.00 | 7.00 | 10.00 | 30.00 | 6.00 | 5.00 | 1.00 | 12.00 | 7.00 | 1.00 | 17.00 | 10.00 | 3.00 | 4.00 |
| 8.00 | 9.00 | 6.00 | 28.00 | 2.00 | 8.00 | 1.00 | 12.00 | 4.00 | 11.00 | 11.00 | 6.00 | 8.00 | 2.00 |
| 7.00 | 8.00 | 15.00 | 18.00 | 9.00 | 5.00 | 1.00 | 19.00 | 7.00 | 9.00 | 6.00 | 5.00 | 6.00 | 2.00 |
| 7.00 | 7.00 | 10.00 | 18.00 | 5.00 | 4.00 | 7.00 | 13.00 | 11.00 | 8.00 | 5.00 | 9.00 | 8.00 | 3.00 |
| 9.00 | 5.00 | 12.00 | 19.00 | 7.00 | 3.00 | 7.00 | 8.00 | 6.00 | 7.00 | 9.00 | 5.00 | 9.00 | 7.00 |
| 11.00 | 7.00 | 11.00 | 24.00 | 8.00 | 4.00 | 5.00 | 15.00 | 4.00 | 5.00 | 7.00 | 9.00 | 3.00 | 6.00 |
| 11.00 | 12.00 | 11.00 | 21.00 | 7.00 | 8.00 | 1.00 | 18.00 | 2.00 | 4.00 | 6.00 | 6.00 | 6.00 | 5.00 |
| 5.00 | 6.00 | 21.00 | 27.00 | 6.00 | 7.00 | 1.00 | 19.00 | 2.00 | 15.00 | 11.00 | 7.00 | 11.00 | 8.00 |
| 7.00 | 9.00 | 12.00 | 12.00 | 8.00 | 3.00 | 2.00 | 11.00 | 6.00 | 4.00 | 9.00 | 11.00 | 4.00 | 7.00 |
| 9.00 | 7.00 | 12.00 | 12.00 | 8.00 | 6.00 | 2.00 | 14.00 | 4.00 | 6.00 | 11.00 | 8.00 | 3.00 | 7.00 |
| 5.00 | 8.00 | 15.00 | 21.00 | 9.00 | 3.00 | 3.00 | 1.00 | 1.00 | 8.00 | 10.00 | 6.00 | 4.00 | 4.00 |
| 359.00 | 386.00 | 635.00 | 1076.00 | 381.00 | 274.00 | 325.00 | 479.00 | 222.00 | 316.00 | 308.00 | 394.00 | 252.00 | 240.00 |
| 7.45 | | 17.11 | | 6.55 | | 8.04 | | 5.38 | | 7.02 | | 4.92 | |
| 1186.10 | | 2927.71 | | 1425.73 | | 1637.66 | | 1259.32 | | 1894.55 | | 1637.61 | |
| | | | 1501.98 | | | | 378.34 | | | | 256.95 | | |
| | | | 13.41 | | | | 3.38 | | | | 3.21 | | |

**APPENDIX 3.** The use of the disc-meter to measure available herbage dry matter (cont...)

**Appendix 3A.** Recorded disc meter height readings, estimated available herbage dry matter ("IN", and "OUT"), and the estimated mean herbage dry matter consumed (kg/animal/day) (cont...)

| 28/2/95 | | 10/3/95 | | | 10/3/95 | | 22/3/95 | | 30/3/95 | | 25/3/95 | | 30/3/95 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V 10 | | V 10 | | | X 51 | | BSS*** | | BSS*** | | BSN*** | | BSN | |
| IN | | OUT | | | IN | | IN | | OUT | | IN | | OUT | |
| 3.00 | 17.00 | 5.00 | 11.00 | 15.00 | 7.00 | 6.00 | 9.00 | 11.00 | 3.00 | 11.00 | 10.00 | 19.00 | 5.00 | 10.00 |
| 7.00 | 9.00 | 3.00 | 5.00 | 11.00 | 5.00 | 5.00 | 8.00 | 11.00 | 4.00 | 10.00 | 10.00 | 14.00 | 10.00 | 9.00 |
| 11.00 | 7.00 | 2.00 | 13.00 | 9.00 | 7.00 | 3.00 | 7.00 | 14.00 | 3.00 | 12.00 | 14.00 | 22.00 | 12.00 | 11.00 |
| 9.00 | 8.00 | 7.00 | 11.00 | 7.00 | 11.00 | 2.00 | 6.00 | 10.00 | 5.00 | 14.00 | 9.00 | 19.00 | 13.00 | 15.00 |
| 11.00 | 7.00 | 11.00 | 15.00 | 10.00 | 3.00 | 9.00 | 10.00 | 11.00 | 6.00 | 7.00 | 6.00 | 19.00 | 8.00 | 12.00 |
| 16.00 | 6.00 | 3.00 | 9.00 | 13.00 | 5.00 | 8.00 | 8.00 | 10.00 | 8.00 | 6.00 | 7.00 | 22.00 | 12.00 | 10.00 |
| 18.00 | 5.00 | 5.00 | 11.00 | 15.00 | 7.00 | 7.00 | 8.00 | 10.00 | 11.00 | 7.00 | 6.00 | 22.00 | 8.00 | 15.00 |
| 19.00 | 9.00 | 3.00 | 7.00 | 17.00 | 9.00 | 11.00 | 9.00 | 5.00 | 13.00 | 10.00 | 7.00 | 19.00 | 8.00 | 18.00 |
| 9.00 | 11.00 | 2.00 | 7.00 | 11.00 | 14.00 | 12.00 | 7.00 | 9.00 | 8.00 | 10.00 | 6.00 | 15.00 | 9.00 | 6.00 |
| 7.00 | 13.00 | 5.00 | 8.00 | 6.00 | 9.00 | 11.00 | 6.00 | 9.00 | 15.00 | 9.00 | 8.00 | 9.00 | 11.00 | 12.00 |
| 13.00 | 10.00 | 2.00 | 5.00 | 13.00 | 11.00 | 9.00 | 10.00 | 16.00 | 12.00 | 11.00 | 12.00 | 16.00 | 6.00 | 11.00 |
| 9.00 | 12.00 | 7.00 | 6.00 | 9.00 | 13.00 | 10.00 | 10.00 | 17.00 | 7.00 | 19.00 | 6.00 | 14.00 | 12.00 | 12.00 |
| 6.00 | 8.00 | 9.00 | 5.00 | 8.00 | 12.00 | 11.00 | 9.00 | 15.00 | 9.00 | 9.00 | 8.00 | 16.00 | 9.00 | 10.00 |
| 11.00 | 12.00 | 6.00 | 7.00 | 7.00 | 6.00 | 13.00 | 11.00 | 13.00 | 10.00 | 14.00 | 5.00 | 19.00 | 5.00 | 5.00 |
| 7.00 | 8.00 | 11.00 | 1.00 | 9.00 | 5.00 | 15.00 | 12.00 | 14.00 | 7.00 | 15.00 | 11.00 | 12.00 | 5.00 | 13.00 |
| 13.00 | 7.00 | 5.00 | 2.00 | 7.00 | 7.00 | 7.00 | 7.00 | 13.00 | 5.00 | 14.00 | 13.00 | 6.00 | 12.00 | 8.00 |
| 11.00 | 13.00 | 9.00 | 9.00 | 9.00 | 11.00 | 13.00 | 7.00 | 11.00 | 9.00 | 7.00 | 15.00 | 15.00 | 7.00 | 9.00 |
| 10.00 | 15.00 | 7.00 | 2.00 | 9.00 | 9.00 | 8.00 | 9.00 | 12.00 | 8.00 | 8.00 | 10.00 | 14.00 | 14.00 | 5.00 |
| 9.00 | 5.00 | 11.00 | 1.00 | 8.00 | 6.00 | 9.00 | 7.00 | 11.00 | 10.00 | 12.00 | 25.00 | 1.00 | 5.00 | 6.00 |
| 6.00 | 9.00 | 6.00 | 3.00 | 7.00 | 7.00 | 7.00 | 12.00 | 9.00 | 13.00 | 6.00 | 22.00 | 2.00 | 11.00 | 4.00 |
| 5.00 | 16.00 | 7.00 | 5.00 | 4.00 | 9.00 | 9.00 | 11.00 | 8.00 | 7.00 | 5.00 | 6.00 | 8.00 | 9.00 | 10.00 |
| 3.00 | 6.00 | 3.00 | 4.00 | 7.00 | 11.00 | 11.00 | 9.00 | 7.00 | 15.00 | 7.00 | 9.00 | 7.00 | 4.00 | 10.00 |
| 7.00 | 11.00 | 5.00 | 6.00 | 5.00 | 6.00 | 5.00 | 6.00 | 14.00 | 5.00 | 10.00 | 13.00 | 4.00 | 5.00 | 6.00 |
| 6.00 | 13.00 | 3.00 | 7.00 | 3.00 | 4.00 | 6.00 | 7.00 | 12.00 | 14.00 | 10.00 | 2.00 | 9.00 | 10.00 | 5.00 |
| 5.00 | 9.00 | 2.00 | 7.00 | 9.00 | 3.00 | 3.00 | 11.00 | 11.00 | 13.00 | 9.00 | 3.00 | 20.00 | 13.00 | 4.00 |
| 11.00 | 11.00 | 1.00 | 9.00 | 13.00 | 7.00 | 7.00 | 10.00 | 10.00 | 15.00 | 10.00 | 7.00 | 8.00 | 10.00 | 8.00 |
| 10.00 | 11.00 | 5.00 | 6.00 | 5.00 | 5.00 | 9.00 | 6.00 | 9.00 | 19.00 | 11.00 | 0.00 | 14.00 | 6.00 | 12.00 |
| 19.00 | 10.00 | 7.00 | 7.00 | 7.00 | 9.00 | 5.00 | 12.00 | 11.00 | 18.00 | 11.00 | 2.00 | 15.00 | 4.00 | 10.00 |
| 21.00 | 6.00 | 8.00 | 7.00 | 9.00 | 13.00 | 4.00 | 5.00 | 9.00 | 7.00 | 13.00 | 5.00 | 12.00 | 9.00 | 4.00 |
| 9.00 | 4.00 | 7.00 | 9.00 | 5.00 | 5.00 | 6.00 | 5.00 | 12.00 | 7.00 | 5.00 | 14.00 | 14.00 | 6.00 | 8.00 |
| 11.00 | 4.00 | 3.00 | 11.00 | 3.00 | 7.00 | 3.00 | 6.00 | 16.00 | 12.00 | 9.00 | 6.00 | 15.00 | 10.00 | 5.00 |
| 18.00 | 5.00 | 5.00 | 6.00 | 6.00 | 9.00 | 11.00 | 7.00 | 12.00 | 8.00 | 6.00 | 5.00 | 15.00 | 3.00 | 4.00 |
| 17.00 | 9.00 | 4.00 | 7.00 | 5.00 | 11.00 | 5.00 | 12.00 | 9.00 | 12.00 | 11.00 | 4.00 | 20.00 | 5.00 | 10.00 |
| 11.00 | 3.00 | 4.00 | 5.00 | 7.00 | 6.00 | 6.00 | 14.00 | 12.00 | 14.00 | 12.00 | 5.00 | 12.00 | 9.00 | 11.00 |
| 13.00 | 7.00 | 7.00 | 6.00 | 9.00 | 5.00 | 9.00 | 12.00 | 10.00 | 12.00 | 7.00 | 10.00 | 15.00 | 5.00 | 4.00 |
| 15.00 | 6.00 | 9.00 | 7.00 | 11.00 | 1.00 | 13.00 | 15.00 | 11.00 | 11.00 | 10.00 | 5.00 | 14.00 | 5.00 | 6.00 |
| 19.00 | 5.00 | 9.00 | 9.00 | 13.00 | 3.00 | 15.00 | 12.00 | 14.00 | 7.00 | 9.00 | 10.00 | 19.00 | 6.00 | 4.00 |
| 19.00 | 13.00 | 11.00 | 8.00 | 5.00 | 5.00 | 5.00 | 12.00 | 15.00 | 8.00 | 8.00 | 14.00 | 17.00 | 6.00 | 3.00 |
| 17.00 | 7.00 | 6.00 | 7.00 | 9.00 | 7.00 | 4.00 | 14.00 | 17.00 | 13.00 | 9.00 | 7.00 | 13.00 | 6.00 | 5.00 |
| 21.00 | 9.00 | 7.00 | 8.00 | 11.00 | 9.00 | 9.00 | 8.00 | 7.00 | 8.00 | 10.00 | 8.00 | 19.00 | 7.00 | 3.00 |
| 11.00 | 11.00 | 13.00 | 9.00 | 7.00 | 2.00 | 13.00 | 9.00 | 9.00 | 5.00 | 8.00 | 5.00 | 19.00 | 5.00 | 7.00 |
| 6.00 | 7.00 | 11.00 | 7.00 | 6.00 | 3.00 | 15.00 | 12.00 | 12.00 | 12.00 | 5.00 | 5.00 | 15.00 | 4.00 | 7.00 |
| 5.00 | 4.00 | 6.00 | 5.00 | 3.00 | 5.00 | 7.00 | 13.00 | 10.00 | 14.00 | 11.00 | 7.00 | 18.00 | 3.00 | 15.00 |
| 4.00 | 3.00 | 5.00 | 13.00 | 5.00 | 10.00 | 11.00 | 11.00 | 11.00 | 6.00 | 7.00 | 11.00 | 15.00 | 7.00 | 13.00 |
| 7.00 | 6.00 | 3.00 | 11.00 | 9.00 | 5.00 | 5.00 | 6.00 | 11.00 | 14.00 | 10.00 | 22.00 | 14.00 | 8.00 | 12.00 |
| 5.00 | 15.00 | 2.00 | 13.00 | 11.00 | 3.00 | 4.00 | 15.00 | 14.00 | 7.00 | 9.00 | 6.00 | 9.00 | 10.00 | 14.00 |
| 3.00 | 3.00 | 3.00 | 4.00 | 3.00 | 7.00 | 3.00 | 16.00 | 16.00 | 14.00 | 7.00 | 14.00 | 8.00 | 13.00 | 7.00 |
| 7.00 | 4.00 | 2.00 | 7.00 | 5.00 | 5.00 | 2.00 | 11.00 | 12.00 | 8.00 | 11.00 | 3.00 | 7.00 | 12.00 | 8.00 |
| 9.00 | 9.00 | 5.00 | 7.00 | 11.00 | 9.00 | 5.00 | 15.00 | 14.00 | 12.00 | 6.00 | 5.00 | 13.00 | 14.00 | 8.00 |
| 11.00 | 7.00 | 9.00 | 9.00 | 6.00 | 11.00 | 7.00 | 11.00 | 15.00 | 11.00 | 4.00 | 12.00 | 21.00 | 8.00 | 9.00 |
| 530.00 | 425.00 | 291.00 | 364.00 | 412.00 | 359.00 | 393.00 | 485.00 | 581.00 | 494.00 | 471.00 | 435.00 | 704.00 | 404.00 | 433.00 |
| 9.55 | | 7.11 | | | 7.52 | | 10.66 | | 9.65 | | 11.39 | | 8.37 | |
| 1846.65 | | 1519.94 | | | 1396.80 | | 2010.31 | | 1866.65 | | 2114.14 | | 1684.60 | |
| | | 326.72 | | | | | | | 143.66 | | | | 429.54 | |
| | | 2.04 | | | | | | | 4.48 | | | | | |

**APPENDIX 3.** The use of the disc meter to measure available herbage dry matter (cont...)

**Appendix 3B.** Intake of kikuyu dry matter (kg/animal/day) collectively estimated using the pasture disc meter

| Period | Camp | "IN"[1] (kg) | "OUT"[2] (kg) | Total intake (n=16) over period (kg) | Intake/head/day (kg) | S.E |
|---|---|---|---|---|---|---|
| 8-13 D | BSS | 1359 | 981 | 378 | 4.73 | 4.66 |
| 15-20 D | BSN | 1383 | 854 | 529 | 6.61 | 4.80 |
| 29 D-3 J | X52 | 548 | 582 | 0[4] | 0 | 3.50 |
| 5 J-12 J | BSS | 1871 | 1394 | 476 | 4.25 | 2.73 |
| 12 J-19 J | BSN | 1476 | 1082 | 394 | 3.52 | 3.17 |
| 19 J-26 J | Y10 | 2503 | 1764 | 738 | 6.59 | 1.87 |
| 26 J-2 F | V10 | 1652 | 1634 | 18 | 0.28 | 2.15 |
| 2 F-9 F | X51[3] | 1737 | 1283 | 454 | | |
| 6 F-9 F | X52[3] | 1063 | 1186 | 0[4] | 4.05 | 5.58 |
| 9 F-16 F | BSS | 2928 | 1426 | 1501 | 13.4 | 2.94 |
| 16 F-23 F | BSN | 1638 | 1259 | 378 | 3.38 | 2.93 |
| 23 F-28 F | Y10 | 1895 | 1638 | 257 | 3.21 | 2.69 |
| 28 F-10 M | V10 | 1847 | 1520 | 327 | 2.04 | 1.42 |
| 22M-30M | BSS[3] | 2010 | 1867 | 144 | | |
| 25M-30M | BSN[3] | 2114 | 1685 | 430 | 6.49 | 5.64 |
| MEAN | | 1735 | 1344 | 402 | 4.5 | 1.01 |

[1] total available herbage on entering camp.

[2] total available herbage on leaving camp.

[3] camps grazed simultaneously.

[4] intake values set to zero where negative intakes were predicted.

**APPENDIX 3**. The use of the disc meter to measure available herbage dry matter (cont...)

**Appendix 3C.** Example calculation of the S.E. of the available herbage dry matter predicted using the disc meter

Available herbage DM on entry into camp BSS on 9 Nov. 1994 = 1629.12 kg, and :

$$S.E = RSD\sqrt{\frac{1}{m} + \frac{1}{n} + \frac{(\bar{x} - \bar{X})^2}{\sum (X - \bar{X})^2}}$$

(Rayner, 1967)

where: m = no. of disc meter height measurements from which mean disc height is derived (100),

n = no. of calibration points used to establish regression (50),

x (mean) = mean disc height (cm) of points used to measure available herbage (7.98, (Appendix 3A)),

X (mean) = mean disc height (cm) of calibration points (11.82 (Appendix 2A))

and

$$RSD = \frac{\sum [Y - \bar{Y}] - \sum [(X - \bar{X})(Y - \bar{Y})]^2 / \sum (X - \bar{X})^2}{n - 2}$$

(Rayner, 1967)

(26.30, Appendix 2B).

Hence,

$$S.E = 26.30\sqrt{\frac{1}{100} + \frac{1}{50} + \frac{(7.98 - 11.82)^2}{1743.38}}$$

= 5.15 (g/disc area).

Thus S.E. (kg/camp) = 5.15 * (29190.82 / 1000)

= 150.56

## APPENDIX 4. Analysis of the herbage grazed

**Appendix 4A.** Chemical composition of weekly hand-plucked herbage samples taken from the camps in which the trial animals were grazing

| Date | Pasture | DM (%) | Protein (%) | Calcium (%) | Phos. (%) | Fat (%) | Ash (%) | NDF (%) | ADF (%) | GE (MJ/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9/12 | BSS | 28.19 | 20.56 | 0.50 | 0.24 | 2.97 | 8.36 | 50.03 | 24.80 | 17.64 |
| | | 29.83 | 19.93 | 0.50 | 0.23 | 2.76 | 8.54 | | 27.46 | 17.94 |
| 15/12 | BSN | 17.35 | 19.73 | 0.61 | 0.23 | 2.55 | 8.73 | 56.71 | 30.43 | 17.70 |
| | | 16.06 | 21.46 | 0.59 | 0.25 | 2.92 | 9.21 | 54.82 | 28.19 | 17.60 |
| 22/12 | X 51 | 31.43 | 16.90 | 0.50 | 0.18 | 1.57 | 7.34 | 56.99 | 29.41 | 17.49 |
| | | 28.78 | 18.45 | 0.48 | 0.20 | 1.99 | 7.64 | 54.03 | 28.70 | 17.41 |
| 29/12 | X 52 | 27.63 | 15.72 | 0.44 | 0.18 | 1.92 | 6.85 | 57.90 | 29.73 | 17.60 |
| | | 28.45 | 15.82 | 0.42 | 0.18 | 2.06 | 6.81 | 59.38 | 30.67 | 17.79 |
| 5/1 | BSS | 16.93 | 21.81 | 0.61 | 0.31 | 3.32 | 11.60 | 44.36 | 25.58 | 17.47 |
| | | 19.20 | 21.47 | 0.57 | 0.30 | 3.16 | 9.98 | 50.25 | 26.02 | 17.96 |
| 12/1 | BSN | 21.51 | 20.48 | 0.59 | 0.24 | 2.58 | 9.65 | 49.74 | 24.41 | 17.55 |
| | | 21.10 | 20.22 | 0.57 | 0.23 | 3.00 | 9.01 | 49.69 | 25.32 | 17.52 |
| 19/1 | Y 10 | 16.79 | 21.13 | 0.44 | 0.31 | 3.11 | 9.94 | 53.21 | 25.95 | 17.61 |
| | | 18.65 | 20.83 | 0.44 | 0.32 | 3.33 | 9.19 | 53.77 | 24.96 | 17.61 |
| 26/1 | V 10 | 28.52 | 12.09 | 0.49 | 0.19 | 2.42 | 7.44 | 60.59 | 32.14 | 17.20 |
| | | 29.61 | 12.10 | 0.56 | 0.20 | 2.35 | 9.61 | 59.76 | 33.06 | 17.58 |
| 2/2 | X 51 | 22.09 | 18.92 | 0.52 | 0.22 | 2.65 | 8.33 | 55.71 | 26.01 | 17.65 |
| | | 20.74 | 19.19 | 0.47 | 0.24 | 2.98 | 9.34 | 53.62 | 25.55 | 17.68 |
| 9/2 | BSS | 20.78 | 20.20 | 0.58 | 0.29 | 2.84 | 8.47 | 55.39 | 26.16 | 17.69 |
| | | 21.02 | 19.65 | 0.52 | 0.30 | 2.32 | 8.56 | 55.04 | 25.82 | 17.58 |
| 16/2 | BSN | 27.03 | 18.73 | 0.60 | 0.21 | 2.56 | 8.19 | 53.91 | 26.42 | 17.96 |
| | | 28.33 | 18.11 | 0.61 | 0.20 | 2.42 | 7.82 | 57.77 | 27.99 | 18.16 |
| 23/2 | Y 10 | 27.58 | 20.04 | 0.56 | 0.25 | 2.27 | 8.38 | 52.59 | 24.64 | 17.82 |
| | | 28.04 | 20.98 | 0.56 | 0.26 | 2.62 | 8.34 | 54.93 | 24.88 | 18.72 |
| 2/3 | V 10 | 28.91 | 14.23 | 0.21 | 0.21 | 1.91 | 7.06 | 59.49 | 29.87 | 17.93 |
| | | 29.59 | 13.83 | 0.22 | 0.22 | 1.83 | 6.85 | 60.74 | 29.70 | 18.12 |
| 10/3 | X51 | 21.78 | 16.24 | 0.19 | 0.19 | 2.04 | 7.38 | 59.93 | 29.38 | 18.12 |
| | | 23.20 | 16.23 | 0.17 | 0.17 | 2.01 | 6.87 | 62.55 | 29.43 | 18.41 |
| 22/3 | BSS | 21.28 | 17.98 | 0.46 | 0.28 | 2.15 | 8.86 | 56.11 | 26.88 | 18.05 |
| | | 20.92 | 18.18 | 0.50 | 0.27 | 1.79 | 8.53 | 58.04 | 28.46 | 17.76 |
| 30/3 | BSN | 20.53 | 17.23 | 0.48 | 0.27 | 1.98 | 8.26 | 60.68 | 30.66 | 17.70 |
| | | 20.61 | 17.90 | 0.43 | 0.28 | 2.61 | 8.69 | 58.96 | 28.01 | 17.72 |
| Means | | 23.83 | 18.32 | 0.48 | 0.24 | 2.47 | 8.43 | 55.70 | 27.71 | 17.77 |

**APPENDIX 4.** Analysis of the herbage grazed (cont...)

**Appendix 4B.** Results of regression analysis relating the concentrations (%, and MJ/kg for gross energy) of the various chemical fractions of the weekly, hand-plucked herbage samples to time (days) over the duration of the trial

| Fraction | Constant | X - coeff. | S.E. of coeff. | n | $R^2$ | P |
|---|---|---|---|---|---|---|
| DM | 24.64 | -0.01 | 0.04 | 16 | 0.01 | N.S |
| Protein | 22.22 | -0.02 | 0.04 | 16 | 0.02 | N.S |
| Fat | 2.84 | 0.00 | 0.01 | 16 | 0.01 | N.S |
| ADF | 27.36 | 0.00 | 0.02 | 16 | 0.00 | N.S |
| NDF | 58.75 | 0.00 | 0.08 | 16 | 0.00 | N.S |
| Ca | 0.60 | 0.00 | 0.00 | 16 | 0.17 | N.S |
| P | 0.23 | 0.00 | 0.00 | 16 | 0.02 | N.S |
| Ash | 8.95 | -0.01 | 0.01 | 16 | 0.05 | N.S |
| GE | 17.43 | 0.00 | 0.00 | 16 | 0.29 | N.S |

## APPENDIX 5. Growth in animal mass

**Appendix 5A.** Weekly mass values (kg) of the Herefords and Holsteins over the grass only period

| | Weeks from start of trial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Treatment 1 : Herefords | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 8 | | | 200 | 210 | 210 | 217 | 220 | 230 | 232 | 225 | 225 |
| 16 | 225 | 235 | 245 | 252 | 263 | 265 | 262 | 275 | 284 | 275 | 290 |
| 18 | 260 | 273 | 285 | 290 | 276 | 292 | 294 | 310 | 315 | 300 | 310 |
| 33 | 205 | 215 | 225 | 235 | 235 | 250 | 250 | 274 | 276 | 265 | 279 |
| 36 | 307 | 314 | 320 | 340 | 337 | 345 | 350 | 375 | 380 | 358 | 374 |
| 40 | 235 | 241 | 247 | 260 | 263 | 265 | 274 | 290 | 289 | 287 | 298 |
| 61 | 195 | 203 | 210 | 215 | 210 | 220 | 225 | 240 | 242 | 233 | 245 |
| 66 | 205 | 218 | 230 | 243 | 238 | 245 | 250 | 260 | 262 | 265 | 265 |
| Mean | 233 | 242 | 245 | 256 | 254 | 262 | 266 | 282 | 285 | 276 | 286 |
| Treatment 2 : Holsteins | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 19 | 280 | 286 | 292 | 304 | 290 | 300 | 302 | 315 | 305 | 295 | 285 |
| 20 | 315 | 320 | 324 | 325 | 328 | 330 | 325 | 340 | 340 | 327 | 337 |
| 21 | 280 | 285 | 290 | 292 | 279 | 285 | 285 | 295 | 290 | 278 | 285 |
| 22 | 270 | 273 | 275 | 290 | 276 | 270 | 270 | 290 | 290 | 270 | 263 |
| 23 | 295 | 302 | 309 | 310 | 309 | 306 | 290 | 305 | 305 | 290 | 296 |
| 24 | 275 | 274 | 273 | 280 | 273 | 280 | 270 | 275 | 279 | 277 | 278 |
| 25 | 275 | 285 | 295 | 295 | 295 | 295 | 287 | 292 | 292 | 272 | 270 |
| 27 | 286 | 293 | 300 | 308 | 299 | 298 | 285 | 275 | 291 | 285 | 285 |
| Mean | 285 | 290 | 295 | 301 | 294 | 296 | 289 | 298 | 299 | 287 | 287 |

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5B.** Weekly mass values (kg) of the animals in the three treatments over the adaption, and concentrate periods

| | Weeks from start of the trial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Treatment 1 : Herefords (receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 8 | 225 | 235 | 242 | 255 | 255 | 257 | 274 | 275 | 288 | 295 | 291 |
| 16 | 290 | 295 | 295 | 315 | 315 | 315 | 340 | 345 | 349 | 355 | 356 |
| 33 | 279 | 290 | 295 | 305 | 303 | 309 | 330 | 325 | 340 | 345 | 341 |
| 36 | 374 | 387 | 385 | 400 | 410 | 385 | 418 | 425 | 440 | 440 | 440 |
| Mean | 292 | 302 | 304 | 319 | 321 | 317 | 341 | 343 | 354 | 359 | 357 |
| Treatment 2 : Herefords (not receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 18 | 310 | 315 | 317 | 325 | 331 | 332 | 340 | 345 | 357 | 360 | 360 |
| 40 | 298 | 300 | 305 | 307 | 325 | 310 | 335 | 337 | 346 | 350 | 357 |
| 61 | 245 | 255 | 254 | 263 | 275 | 276 | 285 | 285 | 307 | 310 | 306 |
| 66 | 265 | 277 | 275 | 294 | 295 | 305 | 310 | 320 | 322 | 330 | 326 |
| Mean | 280 | 287 | 288 | 297 | 307 | 306 | 318 | 322 | 333 | 338 | 337 |
| Treatment 3 : Holsteins (receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 19 | 285 | 275 | 285 | 301 | 300 | 295 | 307 | 310 | 323 | 330 | 330 |
| 20 | 337 | 347 | 355 | 360 | 372 | 360 | 361 | 365 | 390 | 400 | 400 |
| 21 | 285 | 285 | 290 | 303 | 310 | 305 | 294 | 295 | 305 | 310 | 311 |
| 22 | 263 | 257 | 270 | 280 | 290 | 285 | 297 | 300 | 318 | 320 | 325 |
| 23 | 296 | 310 | 315 | 312 | 307 | 315 | 329 | 330 | 332 | 335 | 335 |
| 24 | 278 | 275 | 270 | 285 | 290 | 292 | 306 | 300 | 300 | 290 | 291 |
| 25 | 270 | 290 | 288 | 305 | 310 | 310 | 320 | 320 | 330 | 345 | 341 |
| 27 | 285 | 285 | 287 | 305 | 305 | 309 | 310 | 310 | 330 | 330 | 326 |
| Mean | 287 | 291 | 295 | 306 | 311 | 309 | 316 | 316 | 329 | 333 | 332 |

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987)

**Model fitted to compare the increase in mass of Herefords to later receive concentrates (H1), and Herefords that would not later receive concentrates (H2), over the grass only period (i.e. test for random allocation to treatment group at the end of the grass only period) :**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 5 | 60182 | 12036.3 | 12.11 |
| Residual | 154 | 153117 | 994.3 | |
| Total | 159 | 213299 | 1341.5 | |
| | | | | |
| Change | -2 | -12309 | 6154.5 | 6.19 |

Percentage variance accounted for = 25.9

***Estimates of regression coefficients***

| | estimate | s.e. | t (154) | P |
|---|---|---|---|---|
| Constant | 236.70 | 10.20 | 23.28 | * * |
| time | 6.04 | 1.64 | 3.68 | * * |
| breed H2 | - 7.00 | 14.40 | - 0.48 | N.S |
| breed Fries | 56.70 | 12.40 | 4.55 | * * |
| time . breed H2 | - 0.71 | 2.32 | - 0.31 | N.S |
| time.breed Fries | - 6.10 | 2.01 | -3.04 | * * |

Conclusion:

1.) Non-significance of time.breed H2 demonstrates that the rate of increase in mass of H1, and H2 were not significantly different over the grass only period, and hence allocation to treatment at the end of this period was not biased in terms of growth rate.

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the increase in mass of breed 1 (Hereford), and breed 2 (Holstein) over the grass only period with all animals included :**

***Summary of analysis***

| | d.f. | s.s | m.s | v.r. |
|---|---|---|---|---|
| Regression | 3 | 57755 | 19251.7 | 19.31 |
| Residual | 156 | 155544 | 997.1 | |
| Total | 159 | 213299 | 1341.5 | 12.25 |
| | | | | |
| Change | - 3 | - 57755 | 19251.7 | 19.31 |

Percentage variance accounted for = 25.7

***Estimates of regression coefficients***

| | estimate | s.e. | t (156) | P |
|---|---|---|---|---|
| breed 1 | 233.18 | 7.20 | 32.40 | * * |
| breed 2 | 293.33 | 7.20 | 40.76 | * * |
| time.breed 1 | 5.68 | 1.16 | 4.89 | * * |
| time.breed 2 | - 0.07 | 1.16 | - 0.06 | N.S |

***Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 11638 | 11638 | 11.39 |
| + breed | 1 | 33902 | 33902 | 33.19 |
| + time.breed | 1 | 12215 | 12215 | 11.96 |
| + Time | 8 | 4355 | 544 | 0.53 **(N.S)** |
| Residual | 148 | 151189 | 1022 | |
| | | | | |
| Total | 159 | 213299 | 1342 | |

Conclusion :

1.) Non-significance of time.breed 2 regression coefficient demonstrates that breed 2 did not have a significant growth rate in terms of mass increase over this period.

**APPENDIX 5 :** Growth in animal mass (cont...)

**Appendix 5.C** : Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

2.) Holsteins had significantly higher initial mass (as estimated by Genstat (1987)) than Herefords ($P < 0.01$).

$$t_{(156)} = \frac{293.33 - 233.18}{\sqrt{7.20^2 + 7.20^2}}$$

$$\underline{= 5.907 ^{**}}$$

3.) Herefords increased in mass at a greater rate than their Holstein counterparts ($P < 0.01$).

$$t_{(156)} = \frac{5.68 + 0.07}{\sqrt{1.16^2 + 1.16^2}}$$

$$\underline{= 3.505 ^{**}}$$

4.) Lack of significance in variance ratio for factor Time shows that deviations from linearity were not significant.

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...) for Period 1 (10 weeks)

**Model fitted to compare the mass increase of the Hereford treatment (breed 1), and the Holstein treatment (breed 2) over the grass only period, with Hereford no. 36 removed :**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 3 | 83065 | 27688.2 | 55.77 |
| Residual | 146 | 72849 | 496.5 | |
| Total | 149 | 155554 | 1044.0 | |
| | | | | |
| Change | - 3 | -83065 | 27688.2 | 55.77 |

Percentage variance accounted for = 52.4

***Estimates of regression coefficients***

| | estimate | s.e. | t (146) | P |
|---|---|---|---|---|
| breed 1 | 221.99 | 5.43 | 40.89 | * * |
| breed 2 | 293.33 | 5.08 | 57.76 | * * |
| time. breed 1 | 5.509 0.787 | 0.876 | 6.29 | * * |
| time. breed 2 | -0.069 - 0.0098 kg/d | 0.820 | -0.08 | N.S |

***Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 8901.1 | 8901.1 | 17.88 |
| + breed | 1 | 63431.5 | 63431.5 | 127.45 |
| + time. breed | 1 | 10731.9 | 10731.9 | 21.56 |
| + Time | 8 | 3804.7 | 475.6 | 0.96 **(N.S)** |
| Residual | 138 | 68684.5 | 497.7 | |
| | | | | |
| Total | 149 | 155553.8 | 1044.0 | |

Conclusions :

1.) Model has far greater reliability when Hereford no. 36 is removed from analysis.

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...) for Period 3 (7 weeks)

**Model fitted to compare the mass increase of the Hereford treatment receiving concentrate (H1), the Hereford treatment not receiving concentrate (H2), and the Holstein treatment (Fries) over the concentrate period.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 5 | 29334 | 5867 | 4.97 |
| Residual | 122 | 143917 | 1180 | |
| Total | 127 | 173251 | 1364 | |
| | | | | |
| Change | -5 | -29334 | 5867 | 4.97 |

Percentage variance accounted for = 13.5

***Estimates of regression coefficients***

| | estimate | | s.e. | t (122) | P |
|---|---|---|---|---|---|
| breed H1 | 226.1 | | 44.1 | 5.12 | * * |
| breed H2 | 217.2 | | 44.1 | 4.92 | * * |
| breed Fries | 249.8 | | 31.2 | 8.00 | * * |
| time.breed H1 | 6.82 | 0.97 | 2.65 | 2.57 | * |
| time.breed H2 | 6.20 | 0.89 | 2.65 | 2.34 | * |
| time.breed Fries | 4.19 | 0.60 | 1.87 | 2.23 | * |

***Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 19227 | 19227 | 15.64 |
| + breed | 2 | 9166 | 4583 | 3.73 |
| + time.breed | 2 | 941 | 471 | 0.38 |
| + Time | 6 | 1316 | 219 | 0.18 **(N.S)** |
| Residual | 116 | 142601 | 1229 | |
| | | | | |
| Total | 127 | 1733251 | 1364 | |

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

Conclusions :

1.) All breeds increased in mass at a rate significantly greater than zero over the concentrate period ($P < 0.01$). For the Holsteins this implies a higher growth rate than the grass only period ($P < 0.05$).

2.) Neither the Hereford treatment receiving concentrate, nor the Hereford treatment eating grass alone increased in mass at a significantly different rate over this period relative to the grass only period.

Hereford treatment 1 (receiving concentrate)

$$t_{(274)} = \frac{6.82 - 5.68}{\sqrt{2.65^2 + 1.16^2}}$$

= 0.4974 (N.S)

Hereford treatment 2 (not receiving concentrate)

$$t_{(274)} = \frac{6.20 - 5.68}{\sqrt{2.65^2 + 1.16^2}}$$

= 0.1798 (N.S.)

3.) There were no significant differences in initial mass (as estimated by Genstat (1987)) between treatments at the start of the concentrate period. This finding was confirmed by t-tests (assuming equal variance) performed on the actual initial masses.

Hereford treatment 2 vs. Hereford treatment 1:

$$t_{(122)} = \frac{226.1 - 217.2}{\sqrt{44.1^2 + 44.1^2}}$$

= 0.143 (N.S)

Hereford treatment 1 vs. Holstein treatment :

$$t_{(122)} = \frac{249.8 - 226.1}{\sqrt{31.2^2 + 44.1^2}}$$

= 0.438 (N.S)

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

Hereford treatment 2 vs. Holstein treatment :

$$t_{(122)} = \frac{249.8 - 217.2}{\sqrt{31.2^2 + 44.1^2}}$$

$\underline{= 0.603\ (N.S)}$

4.) There were no significant differences in rate of increase in mass between treatments over the concentrate period.

Hereford treatment 2 vs. Hereford treatment 1:

$$t_{(122)} = \frac{6.82 - 6.20}{\sqrt{2.65^2 + 2.65^2}}$$

$\underline{= 0.165\ (N.S)}$

Hereford treatment 1 vs. Holstein treatment :

$$t_{(122)} = \frac{6.82 - 4.19}{\sqrt{2.65^2 + 1.87^2}}$$

$\underline{= 0.811\ (N.S)}$

Hereford treatment 2 vs. Holstein treatment :

$$t_{(122)} = \frac{6.20 - 4.19}{\sqrt{2.65^2 + 1.87^2}}$$

$\underline{= 0.620\ (N.S)}$

5.) The lack of significance of the variance ratio for the term Time shows that deviations from linear regression were not significant over this period.

**APPENDIX 5.** Growth in animal mass (cont...)

**Appendix 5C.** Results of regression analysis relating animal mass (kg) to time (weeks) over the duration of the trial, using Genstat V (1987) (cont...)

**Model fitted to compare the increase in mass of the Hereford treatment receiving concentrate (H1), the Hereford treatment not receiving concentrate (H2), and the Holstein treatment (Fries) over the concentrate only period, with Holstein no. 20 removed:**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 5 | 34697 | 6939.5 | 6.99 |
| Residual | 114 | 113237 | 993.3 | |
| Total | 119 | 147934 | 1243.1 | |
| | | | | |
| Change | -5 | -34697 | 6939.5 | 6.99 |

Percentage variance accounted for = 20.1

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed H1 | 226.1 | 40.5 | 5.58 | * * |
| breed H2 | 217.2 | 40.5 | 5.36 | * * |
| breed Fries | 246.2 | 30.6 | 8.04 | * * |
| time.breed H1 | 6.82 | 2.43 | 2.81 | * * |
| time.breed H2 | 6.20 | 2.43 | 2.55 | * |
| time.breed Fries | 3.91 | 1.84 | 2.13 | * |

***Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 17681 | 17681 | 17.04 |
| + breed | 2 | 15923 | 7961 | 7.67 |
| + time.breed | 2 | 1094 | 547 | 0.53 |
| + Time | 6 | 1173 | 195 | 0.19 **(N.S)** |
| Residual | 108 | 112064 | 1038 | |
| | | | | |
| Total | 119 | 147934 | 1243 | |

Conclusions :
1.) Reliability of model is increased when Holstein no. 20 is removed.

## APPENDIX 6. Growth in animal height

**Appendix 6A.** Weekly height values (cm) of the Herefords and Holsteins over the grass only period

| | Weeks from start of trial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Treatment 1 : Herefords | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 8 | | | 102 | 102 | 103 | 103 | 103 | 105 | 104 | 106 | 108 |
| 16 | 108 | 108 | 108 | 106 | 111 | 109 | 112 | 113 | 112 | 112 | 115 |
| 18 | 107 | 107 | 107 | 107 | 105 | 108 | 109 | 108 | 111 | 109 | 111 |
| 33 | 108 | 106 | 103 | 109 | 109 | 110 | 111 | 114 | 112 | 113 | 113 |
| 36 | 109 | 108 | 107 | 108 | 111 | 104 | 110 | 114 | 113 | 112 | 113 |
| 40 | 107 | 107 | 106 | 106 | 109 | 106 | 106 | 112 | 108 | 109 | 113 |
| 61 | 99 | 99 | 99 | 101 | 102 | 101 | 103 | 104 | 103 | 104 | 105 |
| 66 | 107 | 107 | 106 | 106 | 106 | 107 | 108 | 108 | 108 | 108 | 108 |
| Mean | 106 | 106 | 105 | 106 | 107 | 106 | 108 | 110 | 109 | 109 | 111 |
| Treatment 2 : Holsteins | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 19 | 111 | 111 | 111 | 113 | 112 | 110 | 113 | 114 | 113 | 115 | 114 |
| 20 | 119 | 119 | 119 | 119 | 119 | 120 | 124 | 125 | 124 | 123 | 123 |
| 21 | 118 | 118 | 118 | 117 | 119 | 120 | 121 | 121 | 122 | 121 | 121 |
| 22 | 110 | 112 | 113 | 112 | 113 | 115 | 113 | 114 | 115 | 116 | 114 |
| 23 | 118 | 117 | 115 | 118 | 119 | 121 | 121 | 120 | 120 | 121 | 120 |
| 24 | 116 | 115 | 114 | 116 | 117 | 118 | 116 | 116 | 117 | 118 | 118 |
| 25 | 120 | 123 | 125 | 120 | 122 | 120 | 122 | 121 | 122 | 121 | 120 |
| 27 | 114 | 115 | 115 | 114 | 116 | 116 | 119 | 120 | 118 | 119 | 117 |
| Mean | 116 | 116 | 116 | 116 | 117 | 118 | 119 | 119 | 119 | 119 | 118 |

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6B.** Weekly height values (cm) of the animals in the three treatments over the adaption, and concentrate periods

| | Weeks from start of the trial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Treatment 1 : Herefords (receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 8 | 108 | 106 | 108 | 108 | 109 | 108 | 109 | 107 | 109 | 110 | 110 |
| 16 | 115 | 115 | 116 | 117 | 112 | 114 | 117 | 117 | 118 | 116 | 119 |
| 33 | 113 | 115 | 115 | 115 | 114 | 115 | 116 | 116 | 117 | 119 | 115 |
| 36 | 113 | 113 | 114 | 116 | 116 | 115 | 115 | 115 | 114 | 115 | 115 |
| Mean | 112 | 112 | 113 | 114 | 113 | 113 | 114 | 114 | 114 | 115 | 115 |
| Treatment 2 : Herefords (not receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 18 | 111 | 109 | 108 | 110 | 109 | 113 | 114 | 112 | 114 | 113 | 114 |
| 40 | 113 | 111 | 112 | 115 | 113 | 112 | 114 | 115 | 115 | 114 | 115 |
| 61 | 105 | 105 | 103 | 105 | 102 | 107 | 107 | 105 | 108 | 107 | 107 |
| 66 | 108 | 109 | 110 | 109 | 110 | 111 | 111 | 114 | 111 | 114 | 113 |
| Mean | 109 | 109 | 108 | 110 | 109 | 111 | 111 | 111 | 112 | 112 | 112 |
| Treatment 3 : Holsteins (receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 19 | 114 | 114 | 116 | 115 | 113 | 116 | 116 | 119 | 115 | 120 | 118 |
| 20 | 123 | 123 | 125 | 125 | 124 | 126 | 127 | 125 | 126 | 130 | 129 |
| 21 | 121 | 123 | 120 | 124 | 121 | 121 | 124 | 124 | 123 | 120 | 124 |
| 22 | 114 | 114 | 117 | 116 | 116 | 118 | 119 | 116 | 119 | 120 | 119 |
| 23 | 120 | 123 | 122 | 124 | 122 | 122 | 124 | 123 | 123 | 125 | 125 |
| 24 | 118 | 120 | 118 | 120 | 119 | 120 | 122 | 121 | 120 | 117 | 122 |
| 25 | 120 | 122 | 120 | 122 | 122 | 124 | 124 | 124 | 125 | 126 | 123 |
| 27 | 117 | 117 | 120 | 121 | 118 | 121 | 121 | 120 | 121 | 120 | 121 |
| Mean | 118 | 119 | 120 | 121 | 119 | 121 | 122 | 121 | 121 | 122 | 122 |

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987)

**Model fitted to compare the increase in height of the Hereford treatment (breed 1) with the Holstein treatment (breed 2) over the grass only period.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 3 | 4405 | 1468.41 | 122.5 |
| Residual | 156 | 1825 | 11.70 | |
| Total | 159 | 6230 | 39.18 | |
| Change | - 3 | -4405 | 1468.41 | 122.5 |

Percentage variance accounted for 70.1.

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed 1 | 104.515 | 0.780 | 134.06 | * * |
| breed 2 | 115.696 | 0.780 | 148.40 | * * |
| time.breed 1 | 0.550 | 0.126 | 4.38 | * * |
| time.breed 2 | 0.352 | 0.126 | 2.80 | * * |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 310.23 | 301.23 | 24.97 |
| + breed | 1 | 4089.50 | 4089.50 | 339.00 |
| + time.breed | 1 | 14.51 | 14.51 | 1.20 |
| + Time | 8 | 39.77 | 4.97 | 0.41 **(N.S)** |
| Residual | 148 | 1785.39 | 12.06 | |
| Total | 159 | 6230.39 | 39.18 | |

<u>Conclusions :</u>

1.) Significance of the terms time.breed 1, and time.breed 2 demonstrates that the animals in both treatments increased in height at a significant rate over the grass only period.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

2.) The Holsteins had significantly greater mean height at the start of the trial ($P < 0.01$).

$$t_{(156)} = \frac{115.696 - 104.515}{\sqrt{0.780^2 + 0.780^2}}$$

$$\underline{= 10.14 ^{**}}$$

3.) Differences in rate of increase in height were not significant between the two breeds over this period.

$$t_{(156)} = \frac{0.550 - 0.352}{\sqrt{0.126^2 + 0.126^2}}$$

$$\underline{= 1.11 \text{ (N.S)}}$$

4.) The lack of significance of the variance ratio for the term Time shows that deviations from linear regression were not significant over this period.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the increase in height of the Hereford treatment (breed 1) with the Holstein treatment (breed 2) over the grass only period, with Hereford no. 36 removed.**

```
***Summary of analysis***

                    d.f.        s.s.        m.s.        v.r.
Regression             3        4371     1456.86      124.85
Residual             146        1704       11.67
Total                149        6074       40.77

Change               - 3      - 4371     1456.86      124.85

Percentage variance accounted for 71.4

***Estimates of regression coefficients***

                 estimate          s.e.          t             P
breed 1           104.344         0.832     125.36           * *
breed 2           115.696         0.779     148.60           * *
time.breed 1        0.512         0.134       3.81           * *
time.breed 2        0.352         0.126       2.80           * *

*** Accumulated analysis of variance***

Change              d.f.        s.s.        m.s.        v.r.
+ time                 1      252.38      252.38       20.83
+ breed                1     4109.42     4109.42      339.24
+ time.breed           1        8.77        8.77        0.72
+ Time                 8       32.01        4.00        0.33
Residual             138     6074.28       12.11

Total                149     6074.28       40.77
```

Conclusions :

1.) Reliability of model is not greatly improved by dropping Hereford no.36 from the analysis.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the increase in height of the Hereford treatment receiving concentrate (H1), the Hereford treatment not receiving concentrate (H2), and the Holstein treatment (Fries) over the concentrate period.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 5 | 2634 | 526.71 | 43.13 |
| Residual | 122 | 1490 | 12.21 | |
| Total | 127 | 4123 | 32.47 | |
| | | | | |
| Change | - 5 | -2634 | 526.71 | 43.13 |

Percentage variance accounted for 62.4.

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed H1 | 106.21 | 4.49 | 23.65 | * * |
| breed H2 | 106.63 | 4.49 | 23.74 | * * |
| breed Fries | 115.82 | 3.18 | 36.47 | * * |
| time.breed H1 | 0.424 | 0.270 | 1.57 | N.S. |
| time.breed H2 | 0.296 | 0.270 | 1.10 | N.S. |
| time.breed Fries | 0.327 | 0.191 | 1.71 | N.S. |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 79.23 | 79.23 | 6.30 |
| + breed | 2 | 2552.77 | 1276.38 | 101.49 |
| + time.breed | 2 | 1.56 | 0.78 | 0.06 |
| + Time | 6 | 30.90 | 5.15 | 0.41 **(N.S)** |
| Residual | 116 | 1458.87 | 12.58 | |
| | | | | |
| Total | 127 | 4123.34 | 32.47 | |

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

Conclusions :

1.) Lack of significance of the time.breed terms over this period clearly demonstrates that rate of increase in height was not significant for any of the three treatments over the concentrate period.

2.) Differences in rate of increase in height between treatments were therefore clearly non-significant over the concentrate period.

3.) The lack of significance of the variance ratio for the term Time shows that deviations from linear regression were not significant over this period.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the increase in height of the Hereford treatment receiving concentrate (H1), the Hereford treatment not receiving concentrate (H2), and the Holstein treatment (Fries) over the concentrate period, with Holstein no. 20 removed from analysis.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 5 | 2101 | 420.16 | 38.06 |
| Residual | 114 | 1258 | 11.04 | |
| Total | 119 | 3359 | 28.23 | |
| Change | - 5 | - 2101 | 420.16 | 38.06 |

Percentage variance accounted for 69.6.

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed H1 | 106.21 | 4.27 | 24.87 | * * |
| breed H2 | 106.63 | 4.27 | 24.97 | * * |
| breed Fries | 115.97 | 3.23 | 35.93 | * * |
| time.breed H1 | 0.424 | 0.256 | 1.65 | N.S |
| time.breed H2 | 0.296 | 0.256 | 1.16 | N.S. |
| time.breed Fries | 0.276 | 0.194 | 1.42 | N.S. |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 64.77 | 64.77 | 5.69 |
| + breed | 2 | 2033.51 | 1016.76 | 89.32 |
| + time.breed | 2 | 2.50 | 1.25 | 0.11 |
| + Time | 6 | 28.97 | 4.83 | 0.42 |
| Residual | 108 | 1229.42 | 11.38 | |
| Total | 119 | 3359.17 | 28.23 | |

<u>Conclusion :</u>

1.) Dropping of Holstein no.20 improved the reliability of the model over the concentrate period.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the increase in height of the Hereford treatment (breed 1), with the Holstein treatment (breed 2) over the entire duration of the trial.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 3 | 8911 | 2970.18 | 248.21 |
| Residual | 316 | 3781 | 11.97 | |
| Total | 319 | 12692 | 39.79 | |
| Change | - 3 | - 8911 | 2970.18 | 248.21 |

Percentage variance accounted for 69.9.

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed 1 | 105.031 | 0.560 | 187.65 | * * |
| breed 2 | 115.789 | 0.560 | 206.88 | * * |
| time.breed 1 | 0.4498 | 0.0467 | 9.63 | * * |
| time.breed 2 | 0.3288 | 0.0467 | 7.03 | * * |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 1660.82 | 1660.82 | 133.65 |
| + breed | 1 | 7209.55 | 7209.55 | 580.17 |
| + time.breed | 1 | 40.16 | 40.16 | 3.23 |
| + Time | 18 | 78.28 | 4.35 | 0.35 |
| Residual | 298 | 3703.11 | 12.43 | |
| Total | 319 | 12691.93 | 39.79 | |

Conclusions :

1.) Significance of the two time.breed terms demonstrates that the animals within both breeds increased in height at a rate significantly greater than zero over the entire duration of the trial.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

2.) The rate of height increase was not significantly different between the two breeds over the entire duration of the trial.

$$t_{(316)} = \frac{0.4498 - 0.3288}{\sqrt{0.0467^2 + 0.0467^2}}$$

$$\underline{= 1.832\ (N.S)}$$

3.) The lack of significance of the variance ratio for the term Time shows that deviations from linear regression were not significant.

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the height increase of the Hereford treatment (breed 1), with the Holstein treatment (breed 2) over the entire duration of the trial, where Holstein no. 20 was dropped from the analysis.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 3 | 7450 | 2483.23 | 222.73 |
| Residual | 296 | 3300 | 11.15 | |
| Total | 299 | 10750 | 35.95 | |
| Change | - 3 | - 7450 | 2483.23 | 222.73 |

Percentage variance accounted for 69.0.

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed 1 | 105.031 | 0.540 | 194.41 | * * |
| breed 2 | 115.355 | 0.578 | 199.73 | * * |
| time.breed 1 | 0.4498 | 0.0451 | 9.97 | * * |
| time.breed 2 | 0.3109 | 0.0482 | 6.45 | * * |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 1522.70 | 1522.70 | 130.97 |
| + breed | 1 | 5877.62 | 5877.62 | 505.55 |
| + time.breed | 1 | 49.38 | 49.38 | 4.25 |
| + Time | 18 | 68.11 | 3.78 | 0.33 |
| Residual | 278 | 3232.08 | 11.63 | |
| Total | 299 | 10749.89 | 35.95 | |

**APPENDIX 6.** Growth in animal height (cont...)

**Appendix 6C.** Results of regression analysis relating animal height (cm) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

Conclusions :

1.) When Holstein no.20 is removed from the analysis the Herefords have a significantly higher rate of height increase over the entire duration of the trial.

$$t_{(296)} = \frac{0.4498 - 0.3109}{\sqrt{0.0451^2 + 0.0482^2}}$$

$$\underline{= 2.104\ *}$$

## APPENDIX 7. Trends in condition score

**Appendix 7A.** Weekly condition score values (Mulvaney scale) of the Herefords, and Holsteins over the grass only period

| | Weeks from start of trial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Treatment 1 : Herefords | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 8 | | | 2.50 | 2.50 | 2.50 | | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| 16 | | | 2.50 | 2.50 | 2.50 | | 2.75 | 2.75 | 2.75 | 2.75 | 3.00 |
| 18 | | | 2.50 | 2.75 | 2.75 | | 3.00 | 3.00 | 3.00 | 2.75 | 3.00 |
| 33 | | | 2.00 | 2.25 | 2.50 | | 3.00 | 3.00 | 3.00 | 2.75 | 2.75 |
| 36 | | | 2.50 | 2.75 | 2.75 | | 3.00 | 3.00 | 3.50 | 3.00 | 3.25 |
| 40 | | | 2.50 | 2.75 | 2.50 | | 3.00 | 3.00 | 3.00 | 3.00 | 2.75 |
| 61 | | | 2.50 | 2.50 | 2.50 | | 2.75 | 3.00 | 3.25 | 3.00 | 2.75 |
| 66 | | | 2.00 | 2.75 | 2.50 | | 3.00 | 3.00 | 3.00 | 2.75 | 3.00 |
| Mean | | | 2.38 | 2.59 | 2.56 | | 2.88 | 2.91 | 3.00 | 2.81 | 2.88 |
| Treatment 2 : Holsteins | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 19 | | | 2.50 | 2.50 | 2.50 | | 2.50 | 2.50 | 2.25 | 2.25 | 2.00 |
| 20 | | | 2.00 | 2.00 | 2.75 | | 2.25 | 2.25 | 2.25 | 2.00 | 2.25 |
| 21 | | | 2.50 | 2.50 | 2.25 | | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 22 | | | 2.50 | 2.50 | 2.50 | | 2.25 | 2.25 | 2.25 | 2.00 | 2.00 |
| 23 | | | 2.50 | 2.50 | 2.50 | | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 24 | | | 2.50 | 2.50 | 2.50 | | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 25 | | | 2.50 | 2.50 | 2.50 | | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 27 | | | 2.50 | 2.50 | 2.50 | | 2.00 | 2.00 | 2.25 | 2.00 | 2.00 |
| Mean | | | 2.44 | 2.44 | 2.50 | | 2.13 | 2.13 | 2.13 | 2.03 | 2.03 |

**APPENDIX 7.** Trends in condition score (cont...)

**Appendix 7B.** Weekly condition score values (Mulvaney scale) of the animals in the three treatments over the adaptation, and concentrate periods

| | Weeks from start of the trial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Treatment 1 : Herefords (receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 8 | 2.50 | 2.75 | 3.00 | 3.25 | 3.25 | 3.00 | 3.25 | 3.50 | 3.50 | 3.50 | 3.25 |
| 16 | 3.00 | 3.00 | 3.00 | 3.25 | 3.25 | 3.25 | 3.25 | 3.50 | 3.50 | 3.50 | 3.50 |
| 33 | 2.75 | 3.00 | 3.00 | 3.25 | 3.25 | 3.25 | 3.50 | 3.25 | 3.50 | 3.50 | 3.25 |
| 36 | 3.25 | 3.25 | 3.25 | 3.25 | 3.50 | 3.50 | 3.50 | 3.50 | 3.75 | 3.75 | 3.25 |
| Mean | 2.88 | 3.00 | 3.06 | 3.25 | 3.31 | 3.25 | 3.38 | 3.44 | 3.56 | 3.56 | 3.31 |
| Treatment 2 : Herefords (not receiving concentrates) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 18 | 3.00 | 3.00 | 3.00 | 3.25 | 3.25 | 3.25 | 3.25 | 3.25 | 3.50 | 3.50 | 3.25 |
| 40 | 2.75 | 2.75 | 3.25 | 3.25 | 3.25 | 3.25 | 3.50 | 3.25 | 3.50 | 3.50 | 3.50 |
| 61 | 2.75 | 3.00 | 3.00 | 3.25 | 3.25 | 3.25 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| 66 | 3.00 | 3.25 | 3.25 | 3.00 | 3.25 | 3.25 | 3.50 | 3.50 | 3.75 | 3.75 | 3.50 |
| Mean | 2.88 | 3.00 | 3.13 | 3.19 | 3.25 | 3.25 | 3.44 | 3.38 | 3.56 | 3.56 | 3.44 |
| Treatment 3 : Holsteins (receiving concentrate) | | | | | | | | | | | |
| No. | | | | | | | | | | | |
| 19 | 2.00 | 2.00 | 2.00 | 2.25 | 2.25 | 2.25 | 2.00 | 2.25 | 2.25 | 2.25 | 2.25 |
| 20 | 2.25 | 2.50 | 2.00 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 |
| 21 | 2.00 | 2.00 | 2.00 | 2.25 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 22 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.25 | 2.00 |
| 23 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 24 | 2.00 | 2.00 | 2.00 | 2.00 | 2.25 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 25 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.25 | 2.00 |
| 27 | 2.00 | 2.00 | 2.25 | 2.25 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.25 |
| Mean | 2.03 | 2.06 | 2.03 | 2.13 | 2.09 | 2.06 | 2.03 | 2.06 | 2.06 | 2.13 | 2.09 |

**APPENDIX 7.** Trends in condition score (cont...)

**Appendix 7C.** Results of regression analysis relating animal condition score (Mulvaney scale) to time (weeks) over the duration of the trial, using Genstat (1987)

**Model fitted to compare the change in condition score of the Hereford treatment (breed 1) with the Holstein treatment (breed 2) over the grass only period.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 3 | 12.161 | 4.05354 | 99.10 |
| Residual | 124 | 5.072 | 0.04090 | |
| Total | 127 | 17.232 | 0.13569 | |
| Change | - 3 | - 12.161 | 4.05354 | 99.10 |

Percentage variance accounted for 69.9.

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed 1 | 2.2096 | 0.0760 | 30.12 | * * |
| breed 2 | 2.6908 | 0.0760 | 35.39 | * * |
| time.breed 1 | 0.0707 | 0.0110 | 6.41 | * * |
| time.breed 2 | -0.0714 | 0.0110 | -6.47 | * * |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 0.00009 | 0.00009 | 0.00 |
| + breed | 1 | 8.76758 | 8.76758 | 218.72 |
| + time.breed | 1 | 3.39295 | 3.39295 | 84.64 |
| + Time | 6 | 0.34170 | 0.34170 | 1.42 **(N.S)** |
| Residual | 118 | 4.73010 | 4.73010 | |
| Total | 127 | 17.23242 | 0.13569 | |

Conclusions :

1.) Significance of time.breed terms demonstrates that the Hereford treatment increased in condition ($P < 0.01$), while the Holstein treatment lost condition ($P < 0.01$) over the grass only period.

**APPENDIX 7.** Trends in condition score (cont...)

**Appendix 7C.** Results of regression analysis relating animal condition score (Mulvaney scale) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

2.) Genstat (1987) estimated condition score at the start of the grass only period was significantly higher for the Holsteins relative to the Herefords (P < 0.01).

$$t_{(124)} = \frac{2.6908 - 2.2906}{\sqrt{0.0760^2 + 0.0760^2}}$$

$$\underline{= 3.723 ^{**}}$$

However a t-test (assuming equal variance) performed on the actual condition scores at the start of this period revealed that differences between the treatments were in fact non - significant.

| | ***Variable 1*** | ***Variable2*** |
|---|---|---|
| Mean | 67787 | 2.38 |
| Variance | 0.03 | 0.05 |
| Observations | 8.00 | 8 |
| Pooled Variance | 0.04 | |
| Hypothesized Mean Difference | 0.00 | |
| df | 14.00 | |
| t | 0.61 | |
| P(T<=t) one-tail | 0.28 | |
| t Critical one-tail | 1.76 | |
| P(T<=t) two-tail | 0.55 | |
| t Critical two-tail | 2.14 | |

3.) The lack of significance of the variance ratio for the term Time shows that deviations from linear regression were not significant over this period.

**APPENDIX 7.** Trends in condition score (cont...)

**Appendix 7C.** Results of regression analysis relating animal condition score (Mulvaney scale) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

**Model fitted to compare the change in condition score of the Hereford treatment receiving concentrate (H1), the Hereford treatment not receiving concentrate (H2), and the Holstein treatment (Fries) over the concentrate period.**

***Summary of analysis***

| | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| Regression | 5 | 54.875 | 10.97503 | 705.53 |
| Residual | 122 | 1.898 | 0.01556 | |
| Total | 127 | 56.773 | 0.44703 | |
| | | | | |
| Change | - 5 | - 54.875 | 10.97503 | 705.53 |

Percentage variance accounted for 96.5

***Estimates of regression coefficients***

| | estimate | s.e. | t | P |
|---|---|---|---|---|
| breed H1 | 2.808 | 0.160 | 17.52 | * * |
| breed H2 | 2.607 | 0.160 | 16.26 | * * |
| breed Fries | 2.088 | 0.113 | 18.42 | * * |
| time.breed H1 | 0.03199 | 0.00962 | 3.32 | * * |
| time.breed H2 | 0.04985 | 0.00962 | 5.18 | * * |
| time.breed Fries | -0.0037 | 0.00680 | - 0.05 | N.S |

*** Accumulated analysis of variance***

| Change | d.f. | s.s. | m.s. | v.r. |
|---|---|---|---|---|
| + time | 1 | 0.27625 | 0.27625 | 19.00 |
| + breed | 2 | 54.28564 | 27.14282 | 1867.21 |
| + time.breed | 2 | 0.31327 | 0.15663 | 10.78 |
| + Time | 6 | 0.21554 | 0.03526 | 2.43 * |
| Residual | 116 | 1.68624 | 0.01454 | |
| | | | | |
| Total | 127 | 56.77295 | 0.44703 | |

**APPENDIX 7.** Trends in condition score (cont...)

**Appendix 7C.** Results of regression analysis relating animal condition score (Mulvaney scale) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

Conclusions :

1.) Significance of time breed terms for breeds H1, and H2, but not for breed Fries demonstrates that the two Hereford treatments gained condition over this period ($P < 0.001$), while the Holsteins neither gained, nor lost condition.

2.) Genstat (1987) estimated condition score at the start of the concentrate period showed that the Holsteins had significantly lower condition score than either of the two Hereford treatments ($P < 0.01$). The two Hereford treatments however had similar initial condition score. These results are consistent with t-tests (assuming equal variance) performed on actual condition scores.

Hereford treatment 1 vs. Holstein treatment:

$$t_{(122)} = \frac{2.808 - 2.088}{\sqrt{0.160^2 + 0.113^2}}$$

$$= 3.68^{**}$$

Hereford treatment 2 vs. Holstein treatment :

$$t_{(122)} = \frac{2.607 - 2.088}{\sqrt{0.160^2 + 0.113^2}}$$

$$= 2.65^{**}$$

Hereford treatment 1 vs. Hereford treatment 2 :

$$t_{(122)} = \frac{2.808 - 2.607}{\sqrt{0.160^2 + 0.160^2}}$$

$$= 0.89 \text{ (N.S)}$$

**APPENDIX 7.** Trends in condition score (cont...)

**Appendix 7C.** Results of regression analysis relating animal condition score (Mulvaney scale) to time (weeks) over the duration of the trial, using Genstat (1987) (cont...)

3.) The two Hereford treatments did not increase in condition at a rate significantly different from one another.

$$t_{(122)} = \frac{0.04985 - 0.03199}{\sqrt{0.00962^2 + 0.00962^2}}$$

$= 1.31$ (N.S)

4.) Rate of increase in condition score was lower relative to the grass only period for the Herefords recieving concentrate ($P < 0.01$), and non-significantly different for the Herefords not recieving concentrate.

Hereford treatment 1 (receiving concentrate):

$$t_{(242)} = \frac{0.0707 - 0.03199}{\sqrt{0.0110^2 + 0.00962^2}}$$

$= 3.51$ * *

Hereford treatment 2 (not receiving concentrate):

$$t_{(242)} = \frac{0.0707 - 0.04985}{\sqrt{0.0110^2 + 0.00962^2}}$$

$= 1.90$ (N.S)

5.) Significance of the variance ratio for the term Time shows that deviations from linear regression were significant over this period, and hence a linear model may not be the best way of describing the data.

## APPENDIX 8. Concentrate intake

**Appendix 8A.** Daily concentrate intake (kg) for the animals in the two treatments receiving concentrate over the concentrate period

| | Days from start of concentrate period | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Treatment 1 : Herefords (receiving concentrate) | | | | | | | | | | | | | | | | |
| No. | | | | | | | | | | | | | | | | |
| 8 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.40 | 1.00 | 1.70 | 1.70 | 1.70 | 1.20 | 1.70 | 1.70 |
| 16 | 1.50 | 0.60 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| 33 | 0.00 | 1.40 | 1.40 | 1.50 | 1.40 | 0.80 | 1.40 | 1.20 | 1.40 | 0.60 | 1.60 | 1.40 | 1.50 | 1.20 | 1.40 | 1.40 |
| 36 | | | | | 1.50 | 0.60 | 1.40 | 1.20 | 1.20 | 0.80 | 1.50 | 1.20 | 1.20 | 1.00 | 1.50 | 0.80 |
| Mean | 1.07 | 1.23 | 1.60 | 1.63 | 1.58 | 1.20 | 1.55 | 1.45 | 1.43 | 1.03 | 1.63 | 1.50 | 1.53 | 1.28 | 1.58 | 1.40 |
| Treatment 3 : Holsteins (receiving concentrate) | | | | | | | | | | | | | | | | |
| No. | | | | | | | | | | | | | | | | |
| 19 | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 | 0.60 | 1.40 | 1.00 | 1.50 | 0.80 | 1.50 | 1.00 | 1.50 | 1.00 | 1.50 | 0.80 |
| 20 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| 21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 0.00 | 0.80 | 0.80 | 1.40 | 1.00 | 1.40 | 0.80 |
| 22 | 0.00 | 0.00 | 0.00 | 1.50 | 1.40 | 0.80 | 1.40 | 1.20 | 1.40 | 0.80 | 1.40 | 1.00 | 1.20 | 1.20 | 1.50 | 0.80 |
| 23 | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 | 1.00 | 1.40 | 1.00 | 1.50 | 0.80 | 1.40 | 1.20 | 1.50 | 1.20 | 1.50 | 0.60 |
| 24 | 1.60 | 1.40 | 1.40 | 1.50 | 1.40 | 0.60 | 1.50 | 1.20 | 1.20 | 0.60 | 1.50 | 0.80 | 1.20 | 1.20 | 1.50 | 0.60 |
| 25 | 1.60 | 1.60 | 1.60 | 1.60 | 1.60 | 0.80 | 1.50 | 1.40 | 1.00 | 0.80 | 1.40 | 0.80 | 1.50 | 1.40 | 1.60 | 0.80 |
| 27 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mean | 0.99 | 0.94 | 0.94 | 1.14 | 1.11 | 0.69 | 1.11 | 1.04 | 1.04 | 0.69 | 1.24 | 0.91 | 1.25 | 1.09 | 1.34 | 0.76 |

** Figures in italics indicate estimated intake (1.7kg) over periods where the MFW was out of operation*

**APPENDIX 8.** Concentrate intake (cont...)

**Appendix 8A.** Daily concentrate intake (kg) for the animals in the two treatments receiving concentrate over the concentrate period

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 1.70 | 1.70 | 1.50 | 1.20 | 1.53 | 0.40 | 1.70 | 1.40 | 1.40 | 1.40 | 1.60 | 1.50 | 0.00 | 1.18 |
| 18 | 1.70 | 1.70 | 1.50 | 1.50 | 1.60 | 1.00 | 1.70 | 1.20 | 1.50 | 1.50 | 1.50 | 1.20 | 0.00 | 1.20 |
| 19 | 1.70 | 1.70 | 1.00 | 1.20 | 1.40 | 1.00 | 1.70 | 1.00 | 0.80 | 1.00 | 1.00 | 1.20 | 0.00 | 0.96 |
| 20 | 1.70 | 1.70 | 1.40 | 1.40 | 1.55 | 1.50 | 1.70 | 0.80 | 1.40 | 1.50 | 1.20 | 1.20 | 0.00 | 1.16 |
| 21 | 1.70 | 1.70 | 1.00 | 0.60 | 1.25 | 1.70 | 1.70 | 0.40 | 0.80 | 1.50 | 1.40 | 1.50 | 0.00 | 1.13 |
| 22 | 1.00 | 1.00 | 0.80 | 0.40 | 0.80 | 0.80 | 1.00 | 0.40 | 0.00 | 0.60 | 0.80 | 0.60 | 0.00 | 0.53 |
| 23 | 1.00 | 1.70 | 1.00 | 1.00 | 1.18 | 1.70 | 1.70 | 1.70 | 0.00 | 1.00 | 1.70 | 1.00 | 0.00 | 1.10 |
| 24 | 1.70 | 1.70 | 0.80 | 0.80 | 1.25 | 1.50 | 1.70 | 0.60 | 0.00 | 1.20 | 1.20 | 0.80 | 0.00 | 0.88 |
| 25 | 1.70 | 1.70 | 0.60 | 0.40 | 1.10 | 0.80 | 1.70 | 0.60 | 0.80 | 0.40 | 0.60 | 0.40 | 0.00 | 0.66 |
| 26 | 1.70 | 1.70 | 1.00 | 0.80 | 1.30 | 1.00 | 1.70 | 0.60 | 0.80 | 0.80 | 0.60 | 1.00 | 0.00 | 0.81 |
| 27 | 1.70 | 1.70 | 1.20 | 1.00 | 1.40 | 1.00 | 1.70 | 0.60 | 1.00 | 1.20 | 0.80 | 1.20 | 1.00 | 1.06 |
| 28 | *1.70* | *1.70* | *1.70* | *1.70* | 1.70 | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | 1.70 |
| 29 | *1.70* | *1.70* | *1.70* | *1.70* | 1.70 | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | *1.70* | 1.70 |
| 30 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 0.00 | 1.70 | 1.70 | 1.70 | 0.00 | 1.28 |
| 31 | 1.70 | 1.70 | 0.60 | 1.70 | 1.43 | 1.70 | 1.70 | 1.70 | 0.00 | 1.70 | 1.70 | 1.70 | 0.00 | 1.28 |
| 32 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 0.00 | 1.49 |
| 33 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 0.00 | 1.49 |

## APPENDIX 8. Concentrate intake (cont...)

**Appendix 8A.** Daily concentrate intake (kg) for the animals in the two treatments receiving concentrate over the concentrate period (cont...)

| 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | Total intake (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 80.40 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 81.30 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 67.70 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 61.60 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 72.75 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 69.40 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 82.60 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 53.70 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 0.00 | 1.70 | 1.70 | 56.40 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 69.60 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 69.00 |
| 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 70.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1.49 | 1.49 | 1.49 | 1.49 | 1.49 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.49 | 1.49 | 1.28 | 1.49 | 1.49 | 60.71 |

**APPENDIX 8.** Concentrate intake (cont...)

**Appendix 8B.** Tests for significance in the level of concentrate intake (total intake (kg), and intake expressed on a metabolic mass scale (g/kg $LW^{0.75}$)) between the Hereford, and Holstein treatments.

**t-Test (assuming equal variance) for differences in total concentrate intake (kg) between the two treatments given access to concentrate.**

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 72.75 | 60.71 |
| Variance | 93.82 | 420.84 |
| Observations | 4.00 | 8.00 |
| Pooled Variance | 322.73 | |
| Hypothesized Mean Difference | 0.00 | |
| df | 10.00 | |
| t | 1.09 | |
| P(T<=t) one-tail | 0.15 | |
| t Critical one-tail | 1.81 | |
| P(T<=t) two-tail | 0.30 | |
| t Critical two-tail | 2.23 | |

**t-Test (assuming equal variance) for differences in concentrate intake expressed on a metabolic mass scale (g/kg $LW^{0.75}$) between the two treatments given access to concentrate.**

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 946.68 | 801.88 |
| Variance | 51399.38 | 66854.47 |
| Observations | 4.00 | 8.00 |
| Pooled Variance | 62217.94 | |
| Hypothesized Mean Difference | 0.00 | |
| df | 10.00 | |
| t | 0.95 | |
| P(T<=t) one-tail | 0.18 | |
| t Critical one-tail | 1.81 | |
| P(T<=t) two-tail | 0.37 | |
| t Critical two-tail | 2.23 | |

Conclusion :

1.) Concentrate intake was not significantly different between the Herefords, and the Holsteins either when expressed as a total level, or when differences in body mass were corrected for.

**APPENDIX 8.** Concentrate intake (cont...)

**Appendix 8C.** Results of regression analysis relating ADG to total concentrate intake (kg), and total concentrate intake per unit metabolic mass (g/kg LW$^{0.75}$)

**Regression Output : ADG (kg/day) vs. total concentrate intake (kg) for treatment 1 (Herefords).**

| | | |
|---|---|---|
| Constant | | 0.7962844 |
| S.E. of Y Estimate | | 0.0713649 |
| R Squared | | 0.0013825 |
| No. of Observations | | 4 |
| Degrees of Freedom | | 2 |
| X Coefficient(s) | -0.000224 | |
| S.E. of Coeff. | 0.0042539 | |

$$t_{(2)} = \frac{-0.000224}{0.0042539}$$

$$= \underline{-0.052 \text{ (N.S)}}$$

**Regression Output : ADG (kg/day) vs. total concentrate intake (kg) for treatment 3 (Holsteins).**

| | | |
|---|---|---|
| Constant | | 0.2683547 |
| S.E. of Y Estimate | | 0.3220698 |
| R Squared | | 0.0887478 |
| No. of Observations | | 8 |
| Degrees of Freedom | | 6 |
| X Coefficient(s) | 0.0045361 | |
| S.E. of Coeff. | 0.0059339 | |

$$t_{(6)} = \frac{0.0045631}{0.0059339}$$

$$= \underline{0.764 \text{ (N.S)}}$$

**APPENDIX 8.** Concentrate intake (cont...)

**Appendix 8C.** Results of regression analysis relating ADG to total concentrate intake (kg), and total concentrate intake per unit metabolic mass (g/kg $LW^{0.75}$) (cont...)

**Regression Output : ADG (kg/day) vs. total concentrate intake (g/kg $LW^{0.75}$) for treatment 1 (Herefords).**

| | | |
|---|---|---|
| Constant | | 0.8751542 |
| S.E. of Y Estimate | | 0.0657348 |
| R Squared | | 0.1527319 |
| No. of Observations | | 4 |
| Degrees of Freedom | | 2 |
| X Coefficient(s) | -0.000101 | |
| S.E. of Coeff. | 0.0001674 | |

$$t_{(2)} = \frac{-0.000101}{0.0001674}$$

$$\underline{= -0.603 \text{ (N.S)}}$$

**Regression Output : ADG (kg/day) vs. total concentrate intake (g/kg $LW^{0.75}$) for treatment 3 (Holsteins).**

| | | |
|---|---|---|
| Constant | | 0.3800302 |
| S.E. of Y Estimate | | 0.3325355 |
| R Squared | | 0.028563 |
| No. of Observations | | 8 |
| Degrees of Freedom | | 6 |
| X Coefficient(s) | 0.0002042 | |
| S.E. of Coeff. | 0.0004861 | |

$$t_{(6)} = \frac{0.0002042}{0.0004861}$$

$$\underline{= 0.420 \text{ (N.S)}}$$

## **APPENDIX 9.** Levels of n-alkanes in the herbage grazed

**Appendix 9A.** Levels of n-alkanes in the hand-plucked herbage samples (mg/kg dry matter) taken during the first experiment to determine herbage intake and digestibility.

| Sample no. | C31 | C32 | C33 | C35 |
|---|---|---|---|---|
| 1 | 180.87 | 16.13 | 219.75 | 113.71 |
| 2 | 172.01 | 18.10 | 210.32 | 111.61 |
| 3 | 114.54 | 16.28 | 177.82 | 114.44 |
| 4 | 123.53 | 23.56 | 172.62 | 96.75 |
| 5 | 96.73 | 16.23 | 153.81 | 103.32 |
| 6 | 99.02 | 17.41 | 148.83 | 90.32 |
| 7 | 95.36 | 12.77 | 152.69 | 100.30 |
| 8 | 86.75 | 14.78 | 153.17 | 121.27 |
| 9 | 126.22 | 16.05 | 218.24 | 112.27 |
| 10 | 158.52 | 18.46 | 287.48 | 126.70 |
| 11 | 162.12 | 21.99 | 220.11 | 133.03 |
| 12 | 150.64 | 22.88 | 213.67 | 106.29 |
| 13 | | | | |
| 14 | | | | |
| 15 | 105.96 | 18.28 | 162.00 | 97.27 |
| 16 | 105.02 | 15.56 | 165.92 | 101.21 |
| 17 | 123.58 | 15.70 | 209.33 | 122.57 |
| 18 | 136.15 | 17.06 | 191.15 | 99.88 |
| 19 | 120.66 | 13.95 | 181.13 | 117.20 |
| 20 | 115.19 | 15.67 | 173.76 | 109.56 |
| Means | 126.27 | 17.27 | 189.54 | 109.87 |
| SE | 6.62 | 0.69 | 8.35 | 2.71 |

**APPENDIX 9.** Levels of n-alkanes in the herbage grazed (cont...)

**Appendix 9A.** Levels of n-alkanes in the hand-plucked herbage samples (mg/kg dry matter) taken during the second experiment to determine herbage intake and digestibility (cont...)

| Sample no. | C31 | C32 | C33 | C35 |
|---|---|---|---|---|
| 21 | 159.69 | 23.42 | 292.85 | 208.90 |
| 22 | 120.73 | 30.79 | 238.51 | 207.32 |
| 23 | 125.79 | 27.84 | 269.82 | 260.12 |
| 24 | 132.17 | 23.49 | 248.24 | 190.86 |
| 25 | 129.54 | 16.99 | 229.91 | 154.75 |
| 26 | 122.17 | 14.70 | 223.52 | 157.48 |
| 27 | 114.61 | 21.11 | 213.05 | 148.46 |
| 28 | 127.04 | 15.29 | 239.37 | 172.68 |
| 29 | 154.14 | 17.13 | 280.71 | 190.49 |
| 30 | 145.62 | 14.60 | 250.92 | 151.33 |
| 31 | 149.70 | 40.40 | 280.95 | 199.39 |
| 32 | 111.18 | 19.35 | 236.19 | 192.97 |
| 33 | 124.19 | 16.15 | 249.80 | 182.66 |
| 34 | 122.93 | 16.77 | 253.91 | 181.65 |
| 35 | 118.52 | 16.55 | 266.47 | 202.06 |
| 36 | 108.41 | 17.28 | 228.05 | 165.17 |
| 37 | 140.82 | 36.87 | 282.19 | 199.36 |
| 38 | 186.15 | 29.83 | 283.14 | 169.55 |
| Means | 132.97 | 22.14 | 253.75 | 185.29 |
| SE | 4.66 | 1.86 | 5.63 | 6.39 |

# APPENDIX 10. Levels of n-alkanes in the faecal samples.

## Appendix 10A. Levels of n-alkanes in the faecal grab samples (mg/kg dry matter) taken during the first experiment to determine herbage intake and digestibility

**C 31**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 378.57 | 291.19 | 412.64 | 454.22 | 404.40 | 348.15 | 362.96 | 378.88 |
| 16 | 266.32 | 250.12 | 201.67 | 348.09 | 327.47 | 321.22 | 428.80 | 306.24 |
| 18 | 302.55 | 266.37 | 458.22 | 410.31 | 401.79 | 361.40 | 333.61 | 362.03 |
| 33 | 347.77 | 295.36 | 376.90 | 503.69 | 463.70 | 309.27 | 335.02 | 375.96 |
| 36 | 308.19 | 289.50 | 372.08 | 458.51 | 432.93 | 364.32 | 345.48 | 367.29 |
| 40 | 302.84 | 378.00 | 413.70 | 481.19 | 437.40 | 314.41 | 269.36 | 370.98 |
| 61 | 287.12 | 257.22 | 395.28 | 486.55 | 401.14 | 393.98 | 298.21 | 359.93 |
| 66 | 344.57 | 346.45 | 448.25 | 462.53 | 374.52 | 346.18 | 375.53 | 385.43 |
| Means | 317.24 | 296.78 | 384.84 | 450.64 | 405.42 | 344.87 | 343.62 | 363.34 |
| SE | 12.99 | 15.71 | 28.31 | 17.63 | 14.78 | 10.20 | 17.11 | |
| **Holstein** | | | | | | | | |
| 19 | 317.66 | 282.20 | 294.12 | 354.83 | 347.87 | 329.82 | 364.41 | 327.27 |
| 20 | 324.17 | 299.71 | 315.99 | 409.46 | 406.19 | 328.61 | 297.81 | 340.28 |
| 21 | 314.78 | 293.61 | 344.42 | 361.43 | 371.17 | 319.16 | 316.78 | 331.62 |
| 22 | 304.92 | 275.12 | 286.23 | 342.29 | 285.45 | 260.74 | 249.93 | 286.38 |
| 23 | 383.77 | 268.49 | 318.05 | 330.72 | 315.02 | 305.27 | 301.09 | 317.48 |
| 24 | 283.45 | 282.03 | 344.36 | 317.98 | 299.92 | 265.17 | 275.91 | 295.55 |
| 25 | 266.10 | 290.70 | 353.96 | 355.94 | 352.57 | 300.38 | 300.99 | 317.23 |
| 27 | 316.85 | 283.68 | 398.21 | | 406.12 | 299.62 | 289.39 | 332.31 |
| Means | 313.96 | 284.44 | 331.92 | 353.23 | 348.04 | 301.09 | 299.54 | 318.89 |
| SE | 12.18 | 3.56 | 12.79 | 11.03 | 16.17 | 9.30 | 11.68 | |

**C 32**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 154.76 | 154.65 | 192.05 | 135.89 | 135.06 | 142.92 | 160.97 | 179.38 |
| 16 | 144.56 | 122.44 | 121.94 | 102.06 | 94.25 | 129.33 | 201.54 | 152.69 |
| 18 | 114.05 | 120.08 | 153.59 | 97.64 | 114.06 | 126.95 | 150.72 | 146.18 |
| 33 | 110.29 | 101.89 | 171.13 | 113.72 | 122.27 | 91.60 | 142.29 | 142.20 |
| 36 | 113.30 | 134.11 | 179.84 | 89.94 | 105.11 | 102.31 | 130.77 | 142.56 |
| 40 | 111.93 | 152.13 | 345.75 | 125.50 | 119.31 | 84.72 | 108.53 | 174.64 |
| 61 | 176.69 | 162.21 | 181.91 | 153.93 | 127.97 | 165.60 | 150.91 | 186.54 |
| 66 | 121.03 | 162.61 | 156.14 | 114.81 | 101.15 | 107.01 | 150.45 | 152.20 |
| Means | 130.83 | 138.76 | 187.80 | 116.69 | 114.90 | 118.80 | 149.52 | 159.55 |
| SE | 8.79 | 7.96 | 23.85 | 7.49 | 4.93 | 9.69 | 9.38 | |
| **Holstein** | | | | | | | | |
| 19 | 195.56 | 160.26 | 147.31 | 136.72 | 118.67 | 145.23 | 171.42 | 179.20 |
| 20 | 108.36 | 128.36 | 144.06 | 122.26 | 129.33 | 140.42 | 157.36 | 155.02 |
| 21 | 194.10 | 153.51 | 162.88 | 132.14 | 131.18 | 134.61 | 169.41 | 179.64 |
| 22 | 210.48 | 182.04 | 205.64 | 137.49 | 121.23 | 145.39 | 166.43 | 194.79 |
| 23 | 212.90 | 163.31 | 263.06 | 173.01 | 172.31 | 161.05 | 189.90 | 222.59 |
| 24 | 152.96 | 164.88 | 183.59 | 132.43 | 117.97 | 147.37 | 190.17 | 181.56 |
| 25 | 94.72 | 127.69 | 149.74 | 125.75 | 122.60 | 147.85 | 155.74 | 154.02 |
| 27 | 140.49 | 121.63 | 188.89 | | 138.60 | 136.34 | 174.49 | 150.07 |
| Means | 163.70 | 150.21 | 180.65 | 119.97 | 131.49 | 144.78 | 171.87 | 177.11 |
| SE | 16.38 | 7.69 | 14.15 | 6.33 | 6.34 | 2.91 | 4.58 | |

**APPENDIX 10.** Levels of n-alkanes in the faecal samples (cont...).

**Appendix 10A.** Levels of n-alkanes in the faecal grab samples (mg/kg dry matter) taken during the first experiment to determine herbage intake and digestibility (cont...)

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 742.37 | 594.94 | 976.45 | 843.44 | 708.35 | 561.84 | 788.65 | 869.34 |
| 16 | 511.50 | 594.94 | 342.47 | 456.02 | 394.47 | 444.10 | 763.00 | 584.42 |
| 18 | 586.02 | 594.94 | 981.17 | 777.24 | 650.65 | 482.62 | 593.97 | 777.77 |
| 33 | 610.04 | 594.94 | 791.66 | 878.39 | 690.33 | 432.72 | 623.03 | 770.18 |
| 36 | 547.09 | 594.94 | 713.25 | 806.82 | 744.18 | 554.95 | 713.06 | 779.05 |
| 40 | 536.30 | 594.94 | 975.70 | 1015.10 | 895.10 | 561.12 | 663.72 | 873.66 |
| 61 | 607.21 | 594.94 | 918.38 | 978.92 | 737.56 | 622.07 | 606.46 | 844.26 |
| 66 | 669.11 | 594.94 | 921.60 | 839.35 | 644.50 | 536.13 | 733.79 | 823.23 |
| Means | 601.20 | 594.94 | 827.58 | 824.41 | 683.14 | 524.44 | 685.71 | 790.24 |
| SE | 26.75 | 0.00 | 77.28 | 60.06 | 49.67 | 23.13 | 26.30 | |
| **Holstein** | | | | | | | | |
| 19 | 556.56 | 579.08 | 568.58 | 513.00 | 496.63 | 451.24 | 595.53 | 626.77 |
| 20 | 586.87 | 581.45 | 643.22 | 718.30 | 660.71 | 516.52 | 614.69 | 720.29 |
| 21 | 563.39 | 565.61 | 687.83 | 633.43 | 616.45 | 484.08 | 603.01 | 692.30 |
| 22 | 535.88 | 489.33 | 532.37 | 492.87 | 417.99 | 354.27 | 433.05 | 542.63 |
| 23 | 692.29 | 567.20 | 602.65 | 447.28 | 435.55 | 399.29 | 541.64 | 614.31 |
| 24 | 533.16 | 534.07 | 604.11 | 501.55 | 439.07 | 385.99 | 559.33 | 592.88 |
| 25 | 500.99 | 523.05 | 669.27 | 548.84 | 513.92 | 408.98 | 550.72 | 619.30 |
| 27 | 596.28 | 530.88 | 789.01 | | 673.14 | 455.07 | 585.59 | 604.99 |
| Means | 570.68 | 546.33 | 637.13 | 550.75 | 531.68 | 431.93 | 560.44 | 638.16 |
| SE | 20.46 | 11.41 | 28.24 | 35.46 | 36.87 | 19.14 | 20.40 | |

**C 35**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 529.05 | 418.58 | 408.99 | 369.63 | 345.17 | 341.72 | 380.98 | 465.69 |
| 16 | 349.25 | 341.28 | 215.97 | 308.89 | 256.87 | 296.86 | 445.89 | 369.17 |
| 18 | 408.79 | 354.94 | 377.82 | 360.99 | 338.86 | 347.11 | 334.19 | 420.45 |
| 33 | 409.44 | 373.30 | 348.28 | 347.68 | 307.76 | 270.15 | 319.24 | 395.98 |
| 36 | 369.96 | 359.22 | 346.98 | 340.50 | 322.48 | 308.79 | 346.14 | 399.01 |
| 40 | 354.44 | 354.08 | 367.00 | 339.11 | 311.42 | 263.70 | 272.47 | 377.03 |
| 61 | 433.14 | 367.59 | 393.86 | 369.87 | 323.45 | 369.50 | 333.67 | 431.85 |
| 66 | 487.00 | 446.80 | 418.76 | 400.98 | 339.81 | 338.99 | 386.19 | 469.75 |
| Means | 417.63 | 376.97 | 359.71 | 354.71 | 318.23 | 317.10 | 352.35 | 416.12 |
| SE | 22.58 | 12.89 | 22.53 | 9.66 | 9.99 | 13.54 | 18.38 | |
| **Holstein** | | | | | | | | |
| 19 | 387.33 | 420.42 | 380.20 | 391.80 | 366.01 | 356.33 | 335.64 | 439.62 |
| 20 | 413.11 | 412.70 | 405.88 | 403.33 | 370.74 | 333.99 | 333.56 | 445.55 |
| 21 | 380.81 | 394.33 | 386.78 | 327.89 | 335.67 | 316.70 | 324.17 | 411.06 |
| 22 | 360.06 | 330.52 | 351.83 | 336.83 | 278.06 | 266.26 | 245.69 | 361.54 |
| 23 | 477.30 | 407.84 | 411.97 | 388.38 | 370.82 | 335.73 | 341.15 | 455.53 |
| 24 | 371.89 | 377.13 | 358.04 | 325.35 | 274.74 | 275.25 | 338.92 | 386.89 |
| 25 | 348.73 | 341.46 | 337.91 | 301.18 | 290.59 | 319.06 | 329.78 | 378.12 |
| 27 | 411.16 | 363.28 | 387.33 | | 326.63 | 274.78 | 304.42 | 344.60 |
| Means | 393.80 | 380.96 | 377.49 | 309.35 | 326.66 | 309.76 | 319.16 | 402.86 |
| SE | 14.34 | 11.88 | 9.25 | 15.14 | 14.57 | 11.86 | 11.26 | |

**APPENDIX 10.** Levels of n-alkanes in the faecal samples (cont...).

**Appendix 10B.** Levels of n-alkanes in the faecal grab samples (mg/kg dry matter) taken during the second experiment to determine herbage intake and digestibility

**C 31**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **Means** |
| 8 | 291.36 | 328.90 | | 442.72 | 372.52 | 344.84 | 278.47 | 343.14 |
| 16 | 232.94 | 226.04 | 320.31 | 358.90 | 204.42 | 185.14 | | 254.62 |
| 33 | 307.26 | 379.51 | 314.33 | 371.33 | 282.31 | 284.30 | 268.44 | 315.36 |
| 36 | 230.39 | 249.63 | 270.84 | | | | | 250.28 |
| **Mean** | 265.49 | 296.02 | 301.83 | 390.98 | 286.42 | 271.43 | 273.45 | 297.95 |
| **SE** | 19.80 | 35.47 | 15.59 | 26.12 | 48.57 | 46.55 | 5.02 | |
| **Hereford 2** | | | | | | | | |
| 18 | 301.52 | 329.82 | 408.17 | 332.83 | 296.39 | 310.73 | 295.59 | 325.01 |
| 40 | 282.07 | 307.49 | 408.90 | 349.87 | 290.99 | 288.69 | 235.63 | 309.09 |
| 61 | 289.06 | 314.07 | 462.41 | 331.61 | 243.36 | 267.26 | 250.32 | 308.30 |
| 66 | 281.65 | 435.75 | 329.08 | 449.70 | 322.70 | 352.32 | 299.89 | 353.01 |
| **Mean** | 288.58 | 346.78 | 402.14 | 366.00 | 288.36 | 304.75 | 270.36 | 323.85 |
| **SE** | 4.64 | 30.03 | 27.47 | 28.21 | 16.52 | 18.17 | 16.11 | |
| **Holstein** | | | | | | | | |
| 19 | 287.20 | 280.87 | 432.86 | 338.30 | 280.50 | 364.89 | 241.93 | 318.08 |
| 20 | 257.73 | 254.47 | 311.71 | 267.66 | 232.95 | 247.49 | 216.66 | 255.52 |
| 21 | 281.97 | 277.97 | 249.61 | 326.30 | 250.35 | 265.72 | 366.13 | 288.29 |
| 22 | 249.83 | 280.74 | 279.74 | 278.34 | 278.32 | 244.74 | 218.66 | 261.48 |
| 23 | 182.28 | 210.62 | 276.76 | 303.82 | 252.01 | 229.91 | 198.35 | 236.25 |
| 24 | 221.95 | 224.18 | 267.50 | 295.38 | 220.22 | 223.96 | 203.31 | 236.64 |
| 25 | 256.03 | 265.11 | 351.51 | 292.74 | 236.33 | 236.23 | 277.68 | 273.66 |
| 27 | 275.76 | 248.59 | 354.65 | 244.08 | 243.93 | 274.34 | 206.53 | 263.98 |
| **Means** | 251.59 | 255.32 | 315.54 | 293.33 | 249.33 | 260.91 | 241.15 | 266.74 |
| **SE** | 12.33 | 9.37 | 21.56 | 10.80 | 7.48 | 16.03 | 20.05 | |

**C 32**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 179.48 | 197.80 | | 222.57 | 166.72 | 168.41 | 154.96 | 181.65 |
| 16 | 122.36 | 125.86 | 172.89 | 149.40 | 87.96 | 82.78 | | 123.54 |
| 33 | 139.43 | 181.00 | 148.60 | 159.96 | 106.22 | 116.60 | 125.69 | 136.79 |
| 36 | 114.25 | 139.26 | 168.65 | | | | | 140.72 |
| **Means** | 138.88 | 155.98 | 163.38 | 177.31 | 120.30 | 122.59 | 140.33 | 145.54 |
| **SE** | 14.51 | 15.71 | 7.49 | 22.83 | 23.80 | 24.90 | 14.63 | |
| **Hereford 2** | | | | | | | | |
| 18 | 147.00 | 138.50 | 245.75 | 135.31 | 93.61 | 133.49 | 124.77 | 145.49 |
| 40 | 109.71 | 151.40 | 178.75 | 145.65 | 123.05 | 114.76 | 90.28 | 130.51 |
| 61 | 124.71 | 139.35 | 191.51 | 148.38 | 99.89 | 123.47 | 92.18 | 131.36 |
| 66 | 114.69 | 150.44 | 145.68 | 192.88 | 119.17 | 125.07 | 134.48 | 140.34 |
| **Means** | 124.03 | 144.92 | 190.42 | 155.55 | 108.93 | 124.20 | 110.43 | 136.93 |
| **SE** | 8.27 | 3.47 | 20.82 | 12.76 | 7.19 | 3.84 | 11.27 | |
| **Holstein** | | | | | | | | |
| 19 | 175.69 | 159.36 | 229.65 | 192.70 | 153.12 | 180.54 | 140.38 | 175.92 |
| 20 | 134.43 | 94.84 | 133.44 | 126.67 | 121.07 | 139.87 | 143.47 | 127.68 |
| 21 | 161.34 | 141.84 | 145.84 | 184.91 | 121.65 | 140.63 | 209.30 | 157.93 |
| 22 | 167.89 | 159.07 | 161.44 | 156.84 | 132.04 | 131.40 | 127.10 | 147.97 |
| 23 | 127.87 | 140.57 | 168.05 | 171.82 | 132.74 | 123.24 | 107.85 | 138.88 |
| 24 | 143.39 | 121.27 | 154.15 | 187.82 | 115.38 | 125.54 | 124.92 | 138.93 |
| 25 | 135.07 | 107.28 | 153.74 | 140.41 | 117.59 | 113.22 | 167.63 | 133.56 |
| 27 | 179.37 | 159.03 | 158.38 | 158.69 | 116.59 | 139.82 | 102.92 | 144.97 |
| **Means** | 153.13 | 135.41 | 163.08 | 164.98 | 126.27 | 136.78 | 140.45 | 145.73 |
| **SE** | 7.19 | 8.86 | 10.20 | 8.36 | 4.50 | 7.12 | 12.23 | |

**APPENDIX 10.** Levels of n-alkanes in the faecal samples (cont...).

**Appendix 10B.** Levels of n-alkanes in the faecal grab samples (mg/kg dry matter) taken during the second experiment to determine herbage intake and digestibility (cont...)

**C 33**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 709.87 | 691.89 | | 977.62 | 1004.42 | 709.09 | 576.67 | 778.26 |
| 16 | 651.23 | 538.91 | 671.34 | 826.54 | 381.36 | 364.07 | | 572.24 |
| 33 | 694.96 | 829.57 | 682.15 | 854.71 | 509.55 | 543.27 | 516.77 | 661.57 |
| 36 | 623.44 | 592.82 | 577.86 | | | | | 598.04 |
| **Means** | 669.87 | 663.30 | 643.78 | 886.29 | 631.78 | 538.81 | 546.72 | 654.36 |
| SE | 19.86 | 63.84 | 33.11 | 46.38 | 189.96 | 99.62 | 29.95 | |
| **Hereford 2** | | | | | | | | |
| 18 | 698.33 | 712.01 | 886.15 | 688.17 | 452.90 | 531.09 | 483.13 | 635.97 |
| 40 | 652.47 | 672.81 | 888.58 | 742.66 | 533.27 | 522.96 | 451.52 | 637.75 |
| 61 | 718.56 | 733.86 | 945.85 | 712.61 | 421.53 | 494.18 | 466.17 | 641.82 |
| 66 | 718.30 | 1012.09 | 697.51 | 1043.79 | 626.03 | 650.38 | 570.59 | 759.81 |
| **Means** | 696.92 | 782.69 | 854.52 | 796.81 | 508.43 | 549.65 | 492.85 | 668.84 |
| SE | 15.56 | 77.50 | 54.12 | 83.08 | 45.72 | 34.50 | 26.70 | |
| **Holstein** | | | | | | | | |
| 19 | 617.48 | 600.82 | 863.59 | 691.16 | 490.48 | 618.92 | 440.67 | 617.59 |
| 20 | 633.57 | 598.18 | 602.32 | 583.59 | 399.41 | 436.70 | 392.07 | 520.83 |
| 21 | 709.50 | 654.93 | 570.05 | 701.90 | 463.15 | 494.66 | 688.88 | 611.87 |
| 22 | 565.88 | 605.61 | 514.57 | 615.91 | 472.06 | 429.97 | 392.03 | 513.72 |
| 23 | 452.34 | 504.34 | 567.94 | 657.09 | 457.32 | 421.09 | 374.33 | 490.64 |
| 24 | 568.44 | 520.67 | 538.56 | 652.03 | 397.93 | 396.18 | 373.92 | 492.53 |
| 25 | 655.59 | 552.55 | 628.48 | 604.39 | 426.73 | 421.01 | 489.83 | 539.80 |
| 27 | 704.93 | 586.03 | 681.97 | 580.19 | 419.80 | 481.56 | 374.86 | 547.05 |
| **Means** | 613.47 | 577.89 | 620.93 | 635.78 | 440.86 | 462.51 | 440.82 | 541.75 |
| SE | 29.89 | 17.44 | 39.30 | 16.56 | 12.25 | 25.15 | 38.25 | |

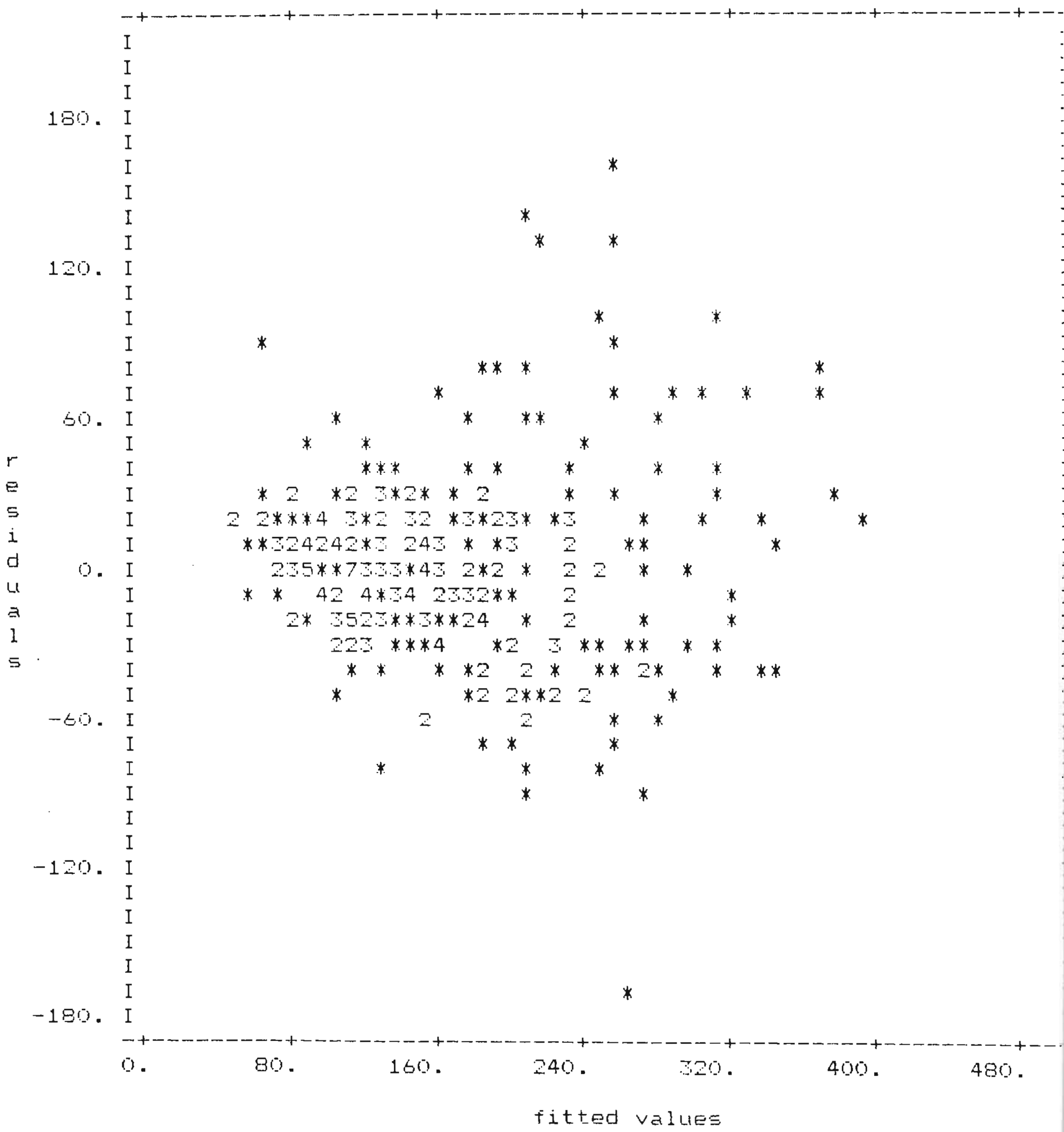
**C 35**

| Animal no. | Day of Faecal Collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Hereford 1** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| 8 | 634.36 | 475.21 | | 460.80 | 481.77 | 462.57 | 416.97 | 488.61 |
| 16 | 655.32 | 464.46 | 473.26 | 515.09 | 375.07 | 348.83 | | 472.01 |
| 33 | 627.65 | 604.94 | 387.98 | 431.21 | 471.69 | 425.74 | 408.90 | 479.73 |
| 36 | 619.92 | 527.31 | 438.14 | | | | | 528.46 |
| **Means** | 634.31 | 517.98 | 433.13 | 469.03 | 442.84 | 412.38 | 412.94 | 474.66 |
| SE | 7.60 | 32.07 | 24.74 | 24.56 | 34.01 | 33.51 | 4.03 | |
| **Hereford 2** | | | | | | | | |
| 18 | 639.29 | 544.69 | 434.46 | 424.75 | 389.61 | 477.37 | 460.53 | 481.53 |
| 40 | 595.57 | 520.54 | 496.52 | 392.82 | 369.18 | 384.79 | 377.25 | 448.10 |
| 61 | 652.60 | 541.30 | 554.15 | 434.37 | 348.31 | 430.51 | 433.15 | 484.91 |
| 66 | 684.30 | 614.44 | 443.87 | 560.02 | 466.65 | 515.21 | 504.31 | 541.26 |
| **Means** | 642.94 | 555.25 | 482.25 | 452.99 | 393.44 | 451.97 | 443.81 | 488.95 |
| SE | 18.40 | 20.44 | 27.58 | 36.76 | 25.82 | 28.31 | 26.59 | |
| **Holstein** | | | | | | | | |
| 19 | 505.55 | 449.63 | 530.13 | 398.15 | 417.46 | 558.36 | 432.97 | 470.32 |
| 20 | 618.07 | 485.81 | 429.51 | 437.67 | 422.45 | 479.50 | 435.79 | 472.68 |
| 21 | 665.27 | 535.10 | 404.31 | 451.41 | 427.38 | 455.86 | 648.99 | 512.62 |
| 22 | 507.92 | 484.36 | 329.45 | 418.37 | 445.61 | 418.37 | 393.23 | 428.19 |
| 23 | 438.27 | 437.81 | 429.92 | 485.11 | 479.45 | 444.01 | 391.07 | 443.66 |
| 24 | 538.74 | 424.05 | 385.12 | 475.22 | 400.97 | 389.33 | 376.09 | 427.07 |
| 25 | 619.26 | 442.34 | 429.68 | 425.42 | 421.44 | 407.64 | 497.37 | 463.31 |
| 27 | 686.16 | 502.46 | 436.88 | 395.45 | 392.81 | 466.46 | 379.07 | 465.61 |
| **Means** | 572.41 | 470.19 | 421.87 | 435.85 | 425.95 | 452.44 | 444.32 | 460.43 |
| SE | 30.94 | 13.41 | 19.97 | 11.72 | 9.52 | 18.60 | 32.53 | |

## APPENDIX 11. Statistical analysis of herbage intake

**Appendix 11A.** Residual plots, of the variate intake, for the first and second experiments to determine herbage intake and digestibility, before log transformation

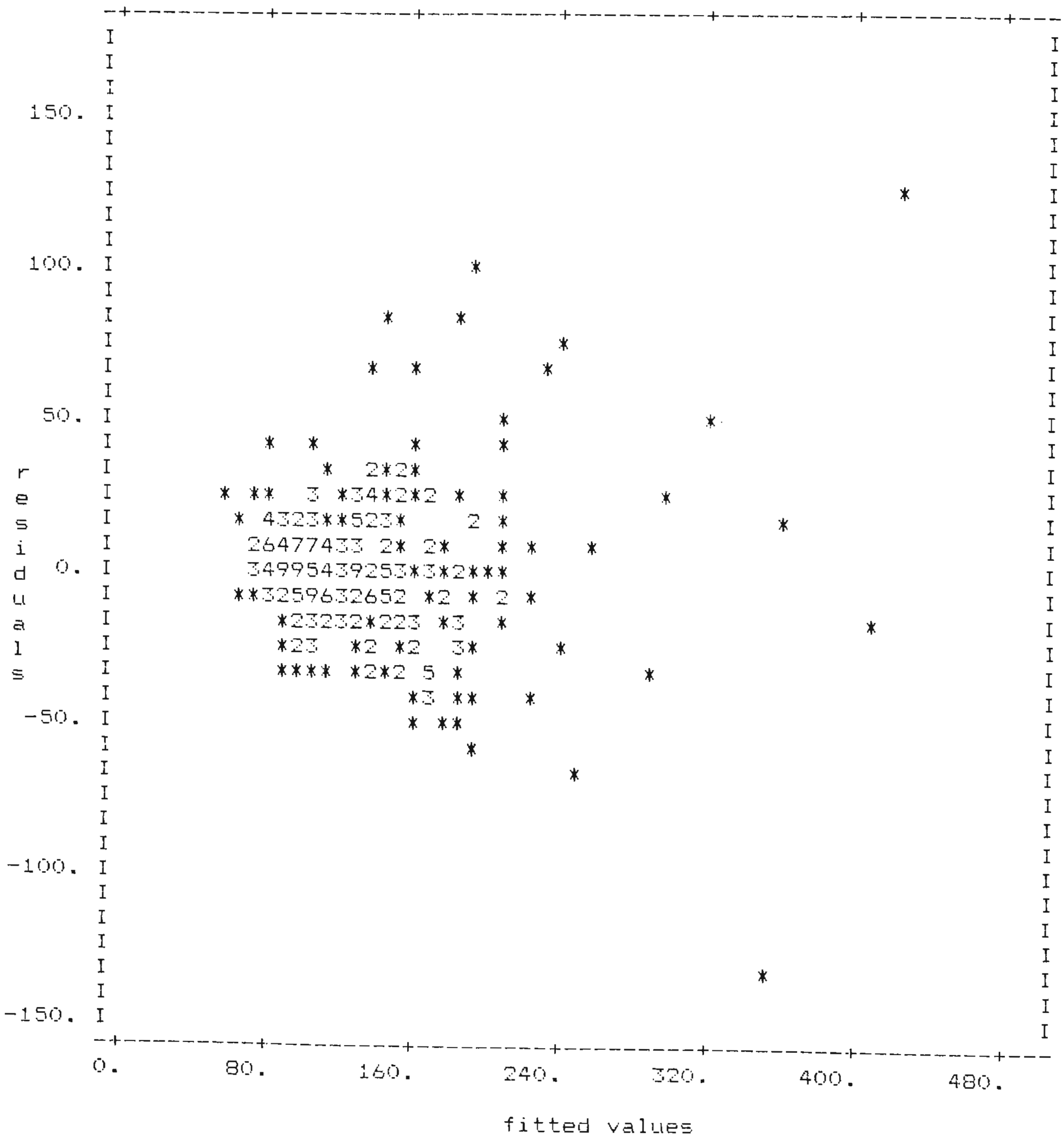
### Experiment 1



**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11A.** Residual plots, of the variate intake, for the first and second experiments to determine herbage intake and digestibility, before log transformation (cont...)

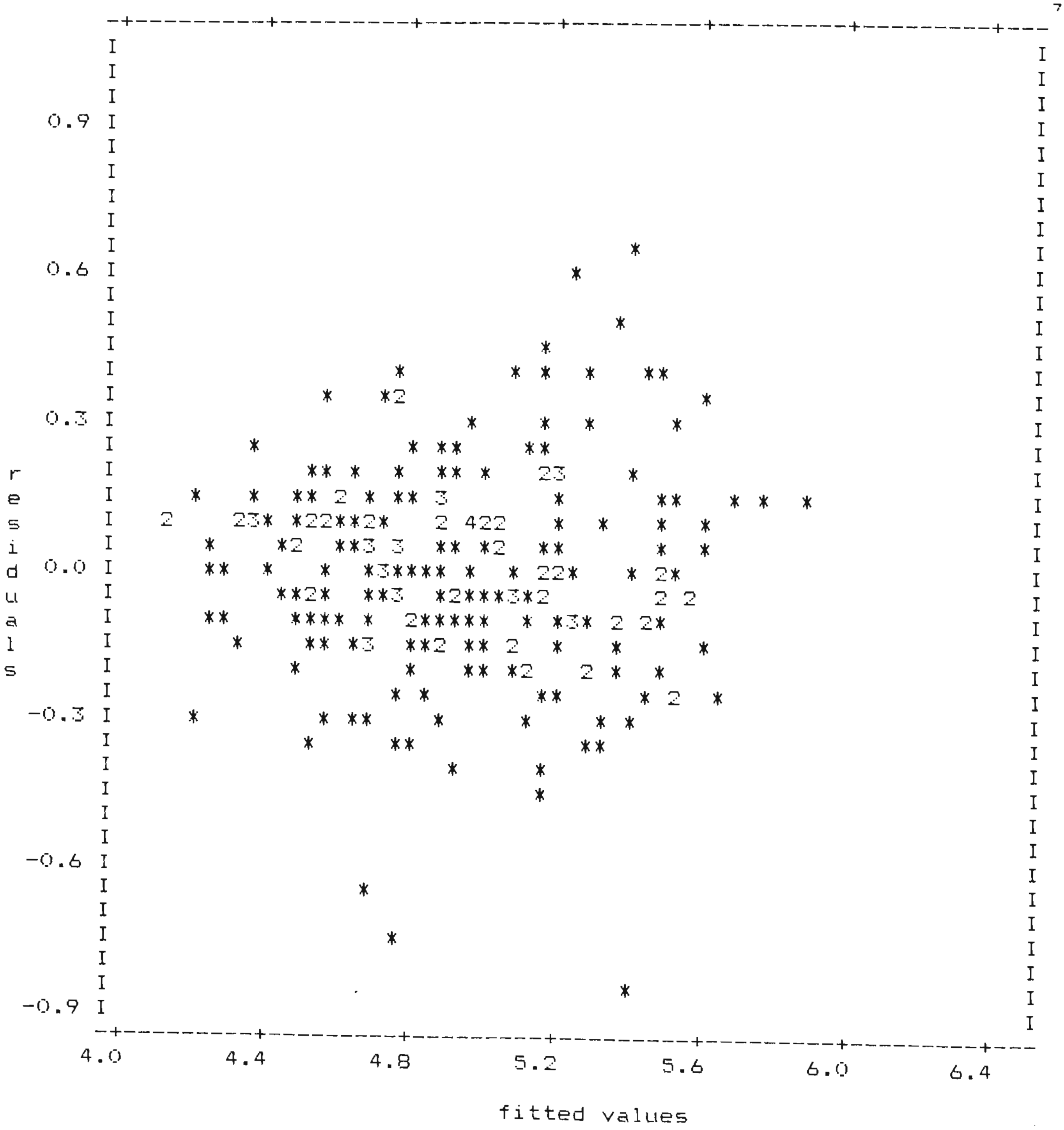
**Experiment 2**



**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11B.** Residual plots, of the variate intake, for the first and second experiments used to determine herbage intake and digestibility, after log transformation

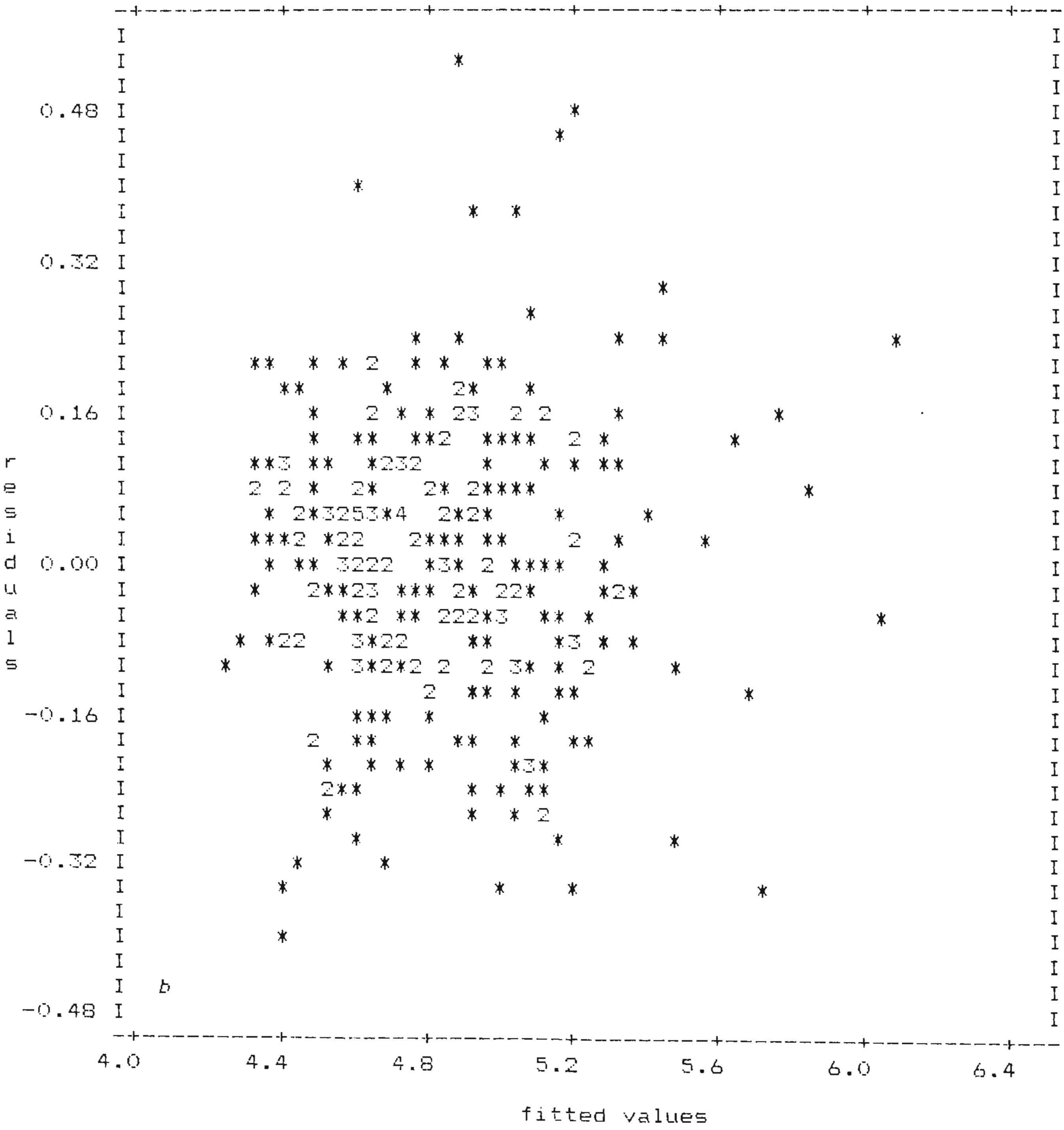
### Experiment 1



**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11B.** Residual plots, of the variate intake, for the first and second experiments used to determine herbage intake and digestibility, after log transformation (cont...)

**Experiment 2**



**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11C.** Breed-method, breed-days, and method-days interactions, for the first and second experiments used to determine herbage intake and digestibility, after log transformation of the dependent variate (intake) (g/kg/L.W$^{0.75}$/d)

**Breed-method interaction**

| **Experiment 1** | Method of intake determination | | | |
|---|---|---|---|---|
| Treatment | $C_{32}$-$C_{33}$ | $C_{31}$-$C_{32}$ | $C_{32}$-$C_{35}$ | Means |
| Hereford | 5.269 | 4.915 | 5.260 | 5.148 |
| Holstein | 4.751 | 4.505 | 4.930 | 4.729 |
| Mean | 5.010 | 4.710 | 5.095 | 4.938 |
| Difference | 0.518 | 0.410 | 0.330 | 0.419 |
| S.E.D. | 0.1016 | | | 0.0587 |
| Significance[1] | ** | ** | ** | ** |
| **Experiment 2** | | | | |
| Hereford[2] (1) conc | 4.910 | 4.687 | 5.001 | 4.866 |
| Hereford[3] (2) grass | 5.081 | 4.968 | 5.137 | 5.062 |
| Holstein (3) | 4.631 | 4.547 | 4.887 | 4.689 |
| Mean | 4.814 | 4.687 | 4.978 | 4.826 |
| Difference (1-2) | -0.172 | -0.281 | -0.136 | -0.196 |
| S.E.D. | 0.0978 | | | 0.0565 |
| Significance[1] | NS | ** | NS | ** |
| Difference (2-3) | 0.450 | 0.421 | 0.250 | 0.373 |
| S.E.D. | 0.0847 | | | 0.0489 |
| Significance[1] | ** | ** | ** | ** |
| Difference (1-3) | 0.278 | 0.140 | 0.114 | 0.177 |
| S.E.D. | 0.0847 | | | 0.0489 |
| Significance[1] | ** | NS | NS | ** |

[1] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

[2] Hereford treatment recieving concentrate in addition to *ad libitum* kikuyu pasture

[3] Hereford treatment recieving *ad libitum* kikuyu pasture alone

**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11C.** Breed-method, breed-days, and method-days interactions, for the first and second experiments used to determine herbage intake and digestibility, after log transformation of the dependent variate (intake) (g/kg/L.W$^{0.75}$/d) (cont...)

**Breed-days interaction**

| **Experiment 1** | Day of faecal collection | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean | S.E.D. |
| Hereford | 5.310 | 5.079 | 4.951 | | | 5.300 | 5.100 | 5.148 | |
| Holstein | 4.854 | 4.834 | 4.719 | | | 4.671 | 4.565 | 4.729 | |
| Mean[1] | $5.082^{a}$ | $4.957^{ab}$ | $4.835^{b}$ | | | $4.985^{a}$ | $4.832^{b}$ | 4.938 | 0.0501 |
| Difference | 0.456 | 0.245 | 0.232 | | | 0.629 | 0.535 | 0.419 | |
| S.E.D. | 0.0863 | | | | | | | 0.0587 | |
| Significance[2] | ** | ** | ** | | | ** | ** | ** | |
| **Experiment 2** | | | | | | | | | |
| Hereford[3] (1) | 5.089 | 4.788 | 4.522 | 4.871 | 5.099 | 4.932 | 4.759 | 4.866 | |
| Hereford[4] (2) | 5.395 | 5.138 | 4.771 | 4.944 | 5.083 | 5.006 | 5.097 | 5.062 | |
| Holstein (3) | 4.766 | 4.854 | 4.620 | 4.603 | 4.723 | 4.677 | 4.577 | 4.689 | |
| Mean[1] | $5.004^{a}$ | $4.908^{b}$ | $4.633^{d}$ | $4.756^{c}$ | $4.907^{b}$ | $4.823^{bc}$ | $4.752^{c}$ | 4.826 | 0.0362 |
| Difference (1-2) | -0.306 | -0.35 | -0.25 | -0.07 | 0.016 | -0.07 | -0.34 | -0.196 | |
| S.E.D. | 0.0877 | | | | | | | 0.0565 | |
| Significance[2] | ** | ** | ** | NS | NS | NS | ** | ** | |
| Difference (2-3) | 0.629 | 0.284 | 0.151 | 0.341 | 0.360 | 0.329 | 0.520 | 0.373 | |
| S.E.D. | 0.0760 | | | | | | | 0.0489 | |
| Significance[2] | ** | ** | (*)[5] | ** | ** | ** | ** | ** | |
| Difference (1-3) | 0.323 | -0.07 | -0.10 | 0.268 | 0.376 | 0.255 | 0.182 | 0.177 | |
| S.E.D. | 0.0760 | | | | | | | 0.0489 | |
| Significance[2] | ** | NS | NS | ** | ** | ** | (*) | ** | |

[1] values with different superscripts (within an experiment) differ significantly ($P < 0.05$)

[2] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

[3] Hereford treatment recieving concentrate in addition to *ad libitum* kikuyu pasture

[4] Hereford treatment recieving *ad libitum* kikuyu pasture alone

[5] brackets indicate comparisons which were not significant before log transformation.

**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11.C.** Breed-method, breed-days, and method-days interactions, for the first and second experiments to determine herbage intake and digestibility, after log transformation of the dependent variate (intake) (g/kg/L.W$^{0.75}$/d) (cont...)

**Method-days interaction**

| **Experiment 1** | Day of faecal collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Method | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
| $C_{32}$-$C_{33}$ (1) | 5.093 | 4.983 | 5.050 | | | 4.919 | 5.002 | 5.010 |
| $C_{31}$-$C_{32}$ (2) | 4.762 | 4.631 | 4.603 | | | 4.937 | 4.616 | 4.710 |
| $C_{32}$-$C_{35}$ (3) | 5.390 | 5.256 | 4.852 | | | 5.099 | 4.879 | 5.095 |
| Mean | 5.082 | 4.957 | 4.835 | | | 4.985 | 4.832 | 4.938 |
| Difference (1-2) | 0.331 | 0.352 | 0.447 | | | -0.02 | 0.386 | -0.300 |
| S.E.D. | 0.1057 | | | | | | | 0.0719 |
| Significance$^2$ | * * | * * | * * | | | NS | * * | * * |
| Difference (2-3) | -0.628 | -0.625 | -0.249 | | | -0.16 | -0.263 | -0.385 |
| Significance$^2$ | * * | * * | (*)[1] | | | | (*) | * * |
| Difference (1-3) | -0.297 | -0.273 | 0.198 | | | -0.18 | 0.123 | -0.085 |
| Significance$^2$ | * * | * | NS | | | NS | NS | NS |
| **Experiment 2** | | | | | | | | |
| $C_{32}$-$C_{33}$ (1) | 4.978 | 4.962 | 4.740 | 4.917 | 4.795 | 4.694 | 4.608 | 4.814 |
| $C_{31}$-$C_{32}$ (2) | 4.576 | 4.688 | 4.629 | 4.689 | 4.844 | 4.750 | 4.634 | 4.687 |
| $C_{32}$-$C_{35}$ (3) | 5.458 | 5.076 | 4.531 | 4.661 | 5.082 | 5.025 | 5.015 | 4.978 |
| Mean | 5.004 | 4.908 | 4.633 | 4.756 | 4.907 | 4.823 | 4.752 | 4.826 |
| Difference (1-2) | 0.402 | 0.274 | 0.111 | 0.228 | -0.05 | -0.06 | -0.026 | 0.127 |
| S.E.D. | 0.0759 | | | | | | | 0.0489 |
| Significance$^2$ | * * | * * | NS | * * | NS | NS | NS | * |
| Difference (2-3) | -0.882 | -0.388 | 0.098 | 0.028 | -0.24 | -0.28 | -0.381 | -0.291 |
| Significance$^2$ | * * | * * | NS | NS | * * | * * | * * | * * |
| Difference (1-3) | -0.480 | -0.114 | 0.209 | 0.256 | -0.29 | -0.33 | -0.407 | -0.164 |
| Significance$^2$ | * * | NS | * * | * * | * * | * * | * * | * * |

[1] brackets indicate comparisons which were not significant before log transformation

[2] NS = not significant; * = $P < 0.05$; ** = $P < 0.01$

**APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11D.** Analysis of variance for intake (for the first and second experiments to determine herbage intake and digestibility) (g/kg/L.W$^{0.75}$) of kikuyu pasture before log transformation

### Experiment 1

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| animal.breed.method stratum | | | | | |
| breed | 1 | 252722 | 252722 | 47.01 | <.001 |
| method | 2 | 148732 | 74366 | 13.83 | <.001 |
| breed.method | 2 | 13670 | 6835 | 1.27 | 0.291 |
| Residual | 42 | 225795 | 5376 | 2.72 | |
| animal.breed.method.days stratum | | | | | |
| days | 4 | 65315 | 16329 | 8.27 | <.001 |
| breed.days | 4 | 31267 | 7817 | 3.96 | 0.004 |
| method.days | 8 | 96843 | 12105 | 6.13 | <.001 |
| breed.method.days | 8 | 16910 | 2114 | 1.07 | 0.386 |
| Residual | 167 (1) | 329623 | 1974 | | |
| Total | 238 (1) | 1148021 | | | |

### Experiment 2

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| animal.breed.method stratum | | | | | |
| breed | 2 | 173065.5 | 86532.8 | 27.94 | <.001 |
| method | 2 | 114221.1 | 57110.5 | 18.44 | <.001 |
| breed.method | 4 | 4033.2 | 1008.3 | 0.33 | N.S. |
| Residual | 39 | 120789.8 | 3097.2 | 3.52 | |
| animal.breed.method.days stratum | | | | | |
| days | 6 | 124841.5 | 20806.9 | 23.66 | <.001 |
| breed.days | 12 | 81171.4 | 6764.3 | 7.69 | <.001 |
| method.days | 12 | 187141.7 | 15595.1 | 17.73 | <.001 |
| breed.method.days | 24 | 47101.8 | 1962.6 | 2.23 | <.001 |
| Residual | 216 (18) | 189959.1 | 879.4 | | |
| Total | 317 (18) | 1002933.6 | | | |

## **APPENDIX 11.** Statistical analysis of herbage intake (cont...)

**Appendix 11E.** Analysis of variance for intake (for the first and second experiments to determine herbage intake and digestibility) (g/kg/L.$W^{0.75}$) of kikuyu pasture after log transformation

### Experiment 1

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| animal.breed.method stratum | | | | | |
| breed | 1 | 10.54834 | 10.54834 | 51.05 | <.001 |
| method | 2 | 6.55339 | 3.27669 | 15.86 | <.001 |
| breed.method | 2 | 0.35472 | 0.17736 | 0.86 | 0.431 |
| Residual | 42 | 8.67783 | 0.20662 | 3.43 | |
| animal.breed.method.days stratum | | | | | |
| days | 4 | 2.15828 | 0.53957 | 8.97 | <.001 |
| breed.days | 4 | 1.48117 | 0.37029 | 6.15 | <.001 |
| method.days | 8 | 2.91590 | 0.36449 | 6.06 | <.001 |
| breed.method.days | 8 | 0.32502 | 0.4063 | 0.68 | 0.713 |
| Residual | 167 (1) | 10.04696 | 0.06016 | | |
| Total | 238 (1) | 42.13917 | | | |

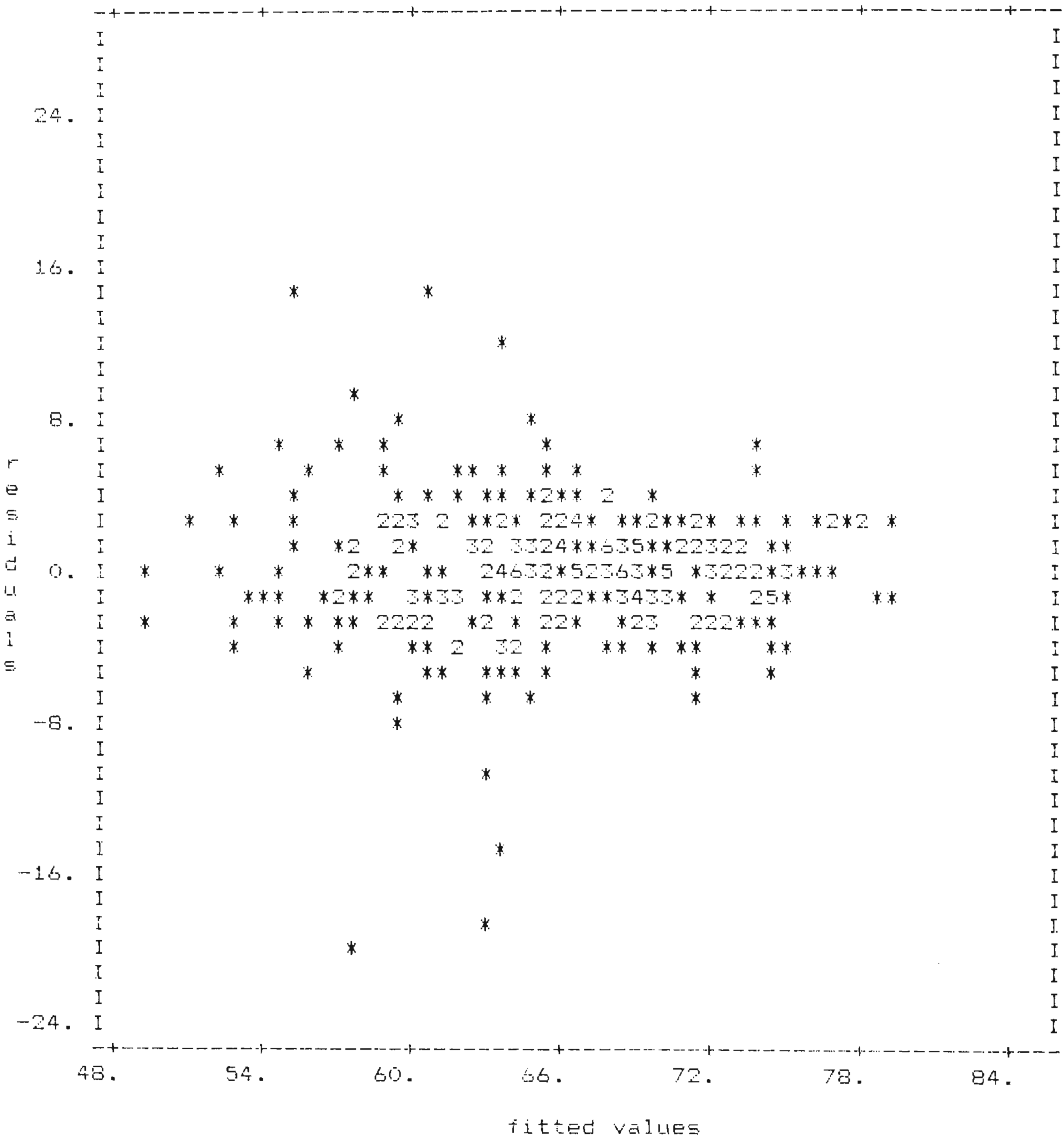
### Experiment 2

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| animal.breed.method stratum | | | | | |
| breed | 2 | 7.98127 | 3.99063 | 29.79 | <.001 |
| method | 2 | 4.77925 | 2.38962 | 17.84 | <.001 |
| breed.method | 4 | 0.62747 | 0.15687 | 1.17 | 0.338 |
| Residual | 39 | 5.22410 | 0.13395 | 4.25 | |
| animal.breed.method.days stratum | | | | | |
| days | 6 | 4.43950 | 0.73992 | 23.47 | <.001 |
| breed.days | 12 | 2.54192 | 0.21183 | 6.72 | <.001 |
| method.days | 12 | 7.13937 | 0.59495 | 18.88 | <.001 |
| breed.method.days | 24 | 0.52938 | 0.02206 | 0.70 | 0.849 |
| Residual | 216 (18) | 6.80838 | 0.03152 | | |
| Total | 317 (18) | 38.30069 | | | |

## APPENDIX 12. Statistical analysis of herbage digestibility

**Appendix 12A.** Residual plots, of the variate digestibility, for the first and second experiments to determine herbage intake and digestibility

### Experiment 1



## APPENDIX 12. Statistical analysis of herbage digestibility

**Appendix 12A.** Residual plots, of the variate digestibility, for the first and second experiments to determine herbage intake and digestibility (cont...)

### Experiment 2