# THE EFFECTS OF FEEDING FREQUENCY ON THE INTAKE AND PERFORMANCE OF COWS GRAZING MIXED PASTURE

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# ABSTRACT

A grazing trial was carried out to compare herbage intake and milk production by dairy cows and observe their grazing behaviour when given all pasture in one break or in four breaks per day.

The experiment was carried out in two periods using a total of 24 animals. Period I with a common herbage allowance of 30 kg DM/cow/day from week 7 to week 9 of lactation and Period II with a common herbage allowance of 40 kg DM/cow/day from week 10 to week 11 of lactation.

The 24 cows which were selected from the high and low breeding index herd were allocated at random to either one break (1B) or four breaks (4B) and used for period I. Sixteen cows were drawn from the 24 cows and used for period II; they were also randomly allocated to the treatments.

Grazing behaviour of cows was observed during Period II of the trial on two separate occasions.

Herbage allowance and herbage intake were estimated by the sward cutting technique. The control group consumed 12.3 and 15.6 kg DM/cow/day while the four breaks (the treatment group) consumed 11.8 and 15.3 kg DM/cow/day for Period I and Period II respectively. Treatment did not have a significant effect.

Milk production, liveweight and body condition score were measured. Treatment had no significant effect on any of these measurements (except for lactose % in Period II).

There was a slight increase in milk production for the treatment group in Period II but the difference was not statistically significant (23.4 versus 22.8 kg milk yield and 1.0 versus 0.9 kg milk fat yield per day).

Grazing time was similar for both groups and there were no significant changes in liveweight and body condition score.

It was concluded that for the condition and herbage allowances used in this experiment, the frequency of herbage allocation had no significant effect on the performance of cows.

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**Common Abbreviations used in this thesis**

| | |
|---|---|
| MY | Milk yield |
| MF | Milk fat |
| MP | Milk protein yield |
| ML | Lactose yield |
| PF | Milk fat concentration (%) |
| PP | Milk protein concentration (%) |
| PL | Lactose concentration (%) |
| LW | Liveweight |
| CS | Body condition score |
| HBI | High breeding index |
| LBI | Low breeding index |
| 1B | One break (B stands for break as a treatment) |
| 4B | Four breaks |
| HM | Pregrazed herbage mass |
| RHM | Residual herbage mass |
| HA | Herbage allowance |
| DM | Dry matter |
| DMI | Dry matter intake |
| DMD | Dry matter digestibility |
| DOMD | Digestible organic matter in the dry matter |
| GE | Gross energy |
| DE | Digestible energy |
| ME | Metabolisable energy |
| MEI | Metabolisable energy intake |
| SEM | Standard error of means |
| GB | Grazing behaviour |
| GT | Grazing time |
| RT | Ruminating time |

# Chapter 1

# INTRODUCTION

Grasslands have long been used by humans for the production of animal products. Animal production from grasslands is determined directly by the amount and quality of fresh and conserved herbage produced and consumed and indirectly by those factors of climate, soil and management that are important for the satisfactory growth and efficient utilisation of herbage.

In the temperate regions dairy cattle feed has been traditionally based on low cost grazing of high quality pasture composed of perennial ryegrass and white clover. Cow requirements are estimated using research data and matched with pasture, access to which is manipulated by grazing management techniques.

Generally herds are seasonally milking, calving in late-winter-early spring to exploit the vigorous grass growth. Surplus spring growth is conserved on the farm as silage or hay. Some herds may calve at other times of the year to cater for the town milk supply.

The adequacy of pasture in meeting the nutritional demands of lactating cows is difficult to assess largely because of numerous plant and animals factors which govern herbage intake in a particular situation. To achieve high milk production and regular reproduction the dairy cow has to be fed well, especially in early lactation when she is more responsive to high levels of feeding. The current and previous plane of nutrition both have an impact on the current performance of the cow.

The voluntary food intake (VFI) and hence production may be hampered by various factors associated with quantity and quality of herbage on offer, management including stocking rates and herbage allowances as well as cow quality. Changes in the feeding system such as increasing the feeding frequency may promote daily food intake and/or increase efficiency of pasture (feed) utilisation. Such changes may alter the grazing (feeding) behaviour of the ruminant.

The effects of feeding frequency of dairy cattle on milk production have been studied extensively. A summary of published results of the effects of frequency of feeding has been given by Gibson (1981, 1984). The diet type in most of these experiments was based on concentrates plus roughage (silage or hay). In New Zealand supplementary feeds are not usually given to dairy cows unless the supply of grazeable herbage is severely limited. Very little research work has been done in New Zealand (e.g. Hancock 1954a, Flux and Patchell 1955) to evaluated the effects of frequency of feeding on milk production on dairy cattle at pasture without any form of supplementation. These trials used low producing cows and examined efficient utilisation of pasture and the control of bloat. The scarcity of this information, especially with high producing dairy cows, prompted this present study.

The primary objectives of this study were to compare the herbage intake and milk production by high producing dairy cows given all pasture in one break or divided into four breaks per 24 hour period and to observe the grazing behaviour of dairy cows.

# Chapter 2

# LITERATURE REVIEW

## 2.1 THE RESPONSE OF DAIRY COWS TO LEVELS OF FEEDING

The dairy cow is the most complex farm animal as she can be growing, lactating and pregnant all at one time. Thus the fate of the dietary nutrients is an interaction among these various physiological demands plus that of maintenance all of which are themselves changing almost continuously (Johnson 1986). The system is a dynamic one in which body reserves are mobilised or deposited at various stages of lactation as well.

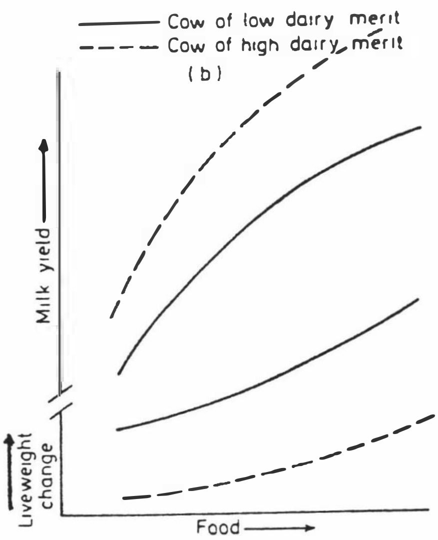
### 2.1.1 THE EFFECT OF FEEDING ON IMMEDIATE MILK PRODUCTION

The immediate response to a change in intake level refers to the change in milk yield, milk composition and liveweight during the period of variable intake. Although the term 'immediate' is employed the development of milk production response to a change in intake level is exponential with 60-70 percent of the effect not being apparent until after seven days and the full effect not being apparent until approximately the twelfth or fourteenth day (Broster 1972, 1974; Combellas and Hodgson, 1979; Hoogendoorn, 1986).

An increase of milk output can be clearly expected as an increasing amount of nutrients is made available to the cow in excess of her maintenance requirements. However it should be remembered that the response in output to increased feed inputs in dairy cows is only a partial response; the energy that is not recovered in milk is largely retained in body tissue as fat (or to the conceptus). This means that in the short term there may be no simple relation between nutrient intake and milk production (Holmes *et al 1981*). Milk yield response to an increased level of feeding and thus energy intake, is negatively curvilinear (Burt, 1957; Broster, 1984; see also Figure 2.1).

The declining response in milk yield with successive increments in energy intake can be explained by an increased rate of diversion of nutrients to tissue deposition (Broster 1972). The joint response of both output pathways to changing intake is linear in energy terms (Broster 1976).

**Figure 2.1 Simplified models to describe the relationships of food to milk and live weight in dairy cows according to responses to level of intake (from Broster 1976)**




The main objective of feeding is to provide an adequate supply of dietary, and hence metabolisable energy, it usually being assumed that the supply of protein will be adequate. However, the amount of protein in the diet does affect its digestibility and therefore the intake.

### 2.1.2 THE EFFECT OF FEEDING ON SUBSEQUENT MILK PRODUCTION

The subsequent (residual) effect is regarded as the prolongation of the effects of differential feeding after this itself has ceased (Broster and Broster 1984). The subsequent effect is expressed relative to the immediate effect measured during the period of differential feeding (Gordon 1976).

Various experiments have been done worldwide on residual effects (Broster and Thomas 1981). In New Zealand for example Bryant and Trigg (1979) studied the effects of short periods of underfeeding in early lactation. They showed a large residual effect from underfeeding in the first three weeks of lactation followed by declining residual effects in the three successive 3-week periods of underfeeding up to week 12 of lactation. In their study in weeks 1-3 and 7-9 the immediate effects were 1.91, 2.81 kg milk from 1.73 and 2.66 kg extra DM respectively. The subsequent effect over 161 and 119 days were +1.04 and +0.49 kg milk on common grazing (Bryant and Trigg 1979).

In another study (Trigg *et al* 1980) underfeeding by 40 percent in early lactation reduced FCM and fat percentage to about 70 percent of those amounts observed with *ad libitum* feeding. These effects disappeared by week 12 of lactation; underfeeding was from 4 to 40 days after calving.

At any given feeding level, a greater response in milk yield to extra nutrients can be expected in the long term due to the potential availability of those nutrients stored as body tissues for subsequent mobilisation in support of milk production. Studies show that milk yield in response to changing feed intake is still negatively curvilinear and generally the response at a given feeding level is greater in the short term (Burt 1957, Broster 1972).

The rate of liveweight (LW) gain following underfeeding in early lactation is generally higher in previously underfed than in previously well fed cows (Bryant and Trigg 1982). Previously underfed cows have been reported to gain 0.15 kg/day more in mid-lactation than those which had been well fed (Broster and Thomas 1981). Originally underfed cows partitioned more digestible energy in later lactation to urine and methane and hence achieved lower ME intakes (Trigg *et al* 1980). In the partition of ME in the energy balances the originally low fed group showed less production, less milk energy and more tissue energy retention.

### 2.1.3 THE EFFECT OF FEEDING ON EFFICIENCY OF MILK PRODUCTION

The partitioning of feed energy between milk production and LW deposition varies between cows. Animals of high genetic merit produce more milk, have greater voluntary intake and use more of their body reserves in early lactation than those of low merit (Bryant and Trigg, 1981; Davey *et al,* 1983; Bauman *et al*, 1985; See Figure 2.1). Hence not all cows operate on a single response curve. At a given level of feeding, milk yield response to extra feeding increases with genetic potential and lactation number and decreases as lactation advances, in direct relation to current yield (Burt 1957, Broster 1976). Therefore cows of high current yield compared to cows of low current yield partition feed energy more towards milk yield and less towards body reserves (Mitchell 1985). Hence, higher yielding cows have a higher gross efficiency and marginal efficiency of milk production.

### 2.1.4 DIET TYPE

The magnitude of the curvilinear response in milk described above varies both with the level of feeding and the type of diet (Johnson 1986). Diet type can affect the partitioning of feed energy and hence the response of milk yield to changes in the level of feeding (Grainger and McGowan 1982). As the level of feeding is increased (with cows supplemented) so the ratio of forage to compound feed usually alters in favour of the later. This can result in depression of digestibility of the forage component, an increased production of propionate with a consequent reduction in the efficiency of utilisation of the dietary energy for milk synthesis and a greater diversion of the ME towards body energy stores.

In contrast to the curvilinear response obtained with cows fed on concentrate/roughage diets, most data that is available for pasture fed cows indicated a linear response in milk yield to increased in feeding level (Bryant 1980, Stockdale *et al* 1981, Grainger *et al* 1982). The differences between pasture and other diets is discussed in Section 2.5.3.2.

## 2.2 FEEDING VALUE OF PASTURE AND ALTERNATIVE METHODS OF ESTIMATING HERBAGE YIELD AND INTAKE FOR RUMINANTS

The value of a forage for animal production, its feeding value, is the product of the amount of a forage an animal will consume (voluntary intake) and the concentration of nutrients contained in the forage and its digestibility (nutritive value) (Holmes 1980). The more nutrients an animal eats in excess of its maintenance requirements, the more nutrients available for the production of milk and/or growth and reproduction. It is therefore important to determine the feeding value, especially intake, of feed for ruminants. Intake particularly of forages is often the factor limiting the total quantity of nutrients especially energy, that an animal can obtain from its ration (Dulphy and Demarquilly 1983). It is considered that voluntary intake contributes at least equally with nutritive value in determining the feeding value of pasture plants (Munro and Walters 1986). Both are in turn determined primarily by the morphology, physiology and chemical composition of grasses and legumes. This section will concentrate on estimation of herbage yield and food intake of pasture; nutritive value will be dealt with in subsequent sections.

### 2.2.1 MEASUREMENT OF FOOD INTAKE AT PASTURE

There are no entirely satisfactory methods for measuring herbage intake and its digestion by the grazing animal (Greenhalgh 1982). A variety of measurement techniques that are available to measure or estimate voluntary intake in the field include the measurements of herbage consumed by cutting to determine dry matter (DM) or other parameters by other indirect methods such as faecal output and herbage digestibility. Faecal output is determined either by total collection of faeces (a cumbersome exercise in the field) or more commonly by feeding the animals a constant daily amount of indicator or indigestible marker not found in the diet, when faecal output is estimated from the daily dose of the marker and its concentration in representative samples of the faeces (Osborn 1980). Recently oral administration of slow release intra-ruminal devices have gained popularity. The digestibility of the herbage consumed is determined either indirectly using *in vitro* methods (Tilley and Terry 1963) on samples of herbage cut or plucked manually or collected from oesophageal fistulated animals or indirectly using faecal indicator such as lignin or n-alkanes (Mayes *et al,* 1986).

An alternative to faecal indicators is the use of the relationship between digestible organic matter intake and faecal nitrogen concentration based on penned animals. Although this relationship is quite good between different levels of intake by similar animals on similar pastures there are wide variations between different situations, necessitating calibration before each experiment; this method is strictly a procedure for estimating dietary digestibility and is not widely adopted for estimating intake (Forbes 1986a). Grazing behaviour (Section 2.6) may be a further possibility of estimating intake (Chacon *et al*, 1976; Arnold, 1985; Hodgson, 1986).

#### 2.2.1.1 Sward Methods of Estimating Herbage Mass

Sward methods for measuring herbage intake are based on the same principle as for indoor experiments where intake is measured by difference:- herbage intake = herbage offered - herbage refused. The herbage mass (total mass of herbage per unit area of ground) is estimated at the beginning and at the end of the grazing period. The difference between the two gives an estimate of the apparent quantity of herbage consumed per unit area. The calculated consumption per unit area is then converted to intake per animal per day (eg kg/cow/day) by dividing by the number of animal-days per unit area after an allowance has been made for the continuance of growth in the sward during the grazing period (Meijs 1982).

Methods of estimating herbage mass can be classified as destructive (cutting) or non-destructive.

(a) Sward Cutting Technique

The simplest harvesting devices are hand operated tools such as scissors, shears and sickles ('t Mannetje 1978). Although these require a high labour input they are useful with small quadrats or with irregular or round ones. The suitability of machinery for herbage sampling depends on the intended height of cutting which in turn depends on the expected height of grazing. The sampling height should reflect the sward management it purports to simulate and should be predetermined, for example 0 cm (cutting close to ground level) may be selected for a trial simulating high grazing pressure with sheep or cattle (Frame 1981, Meijs 1982), i.e. must be below the lowest grazing height. The basic operation is to cut and measure a sample of fresh herbage of a predetermined size and shape and at specified height. Usually 6-10 samples per treatment in a grazing trial are randomly cut.

After collection and washing, the complete sample or sub-sample is oven dried (at about 85-100°C); in some cases the sample for drying may be the bulked sub-sample from a treatment. Drying is necessary since water has no feed value and many subsequent chemical analyses are related to the DM base line (Frame 1981). Contamination with soil (and possibly litter and dung) is inevitable if cutting is at or near ground level (Meijs *et al,* 1982). Therefore the sample should be washed before drying.

The post-grazing herbage mass (residues after grazing) is determined in a similar manner.

(b) Non-destructive techniques

Cutting and weighing methods can be used to calibrate simpler measurements such as visual estimation, measurements of height and density, use of a grassmeter or the electrical capacitance of the sward.

(i) Eye-estimation

The operator must be able to relate what he sees to herbage mass standards with which he has become familiar by training or experience.

Under intensive grazing systems this may involve 3-5 operators who estimate the pasture DM in a paddock or plot. They allow for height, density, species composition and season as they are likely to affect DM production.

(ii) Height and density measurements

Height measurements are likely to be most accurate in short (and undisturbed) swards of simple composition and uniform density. Density is defined as percentage ground cover and is estimated by point quadrat or visual appraisal (Frame, 1981; Meijs *et al*, 1982).

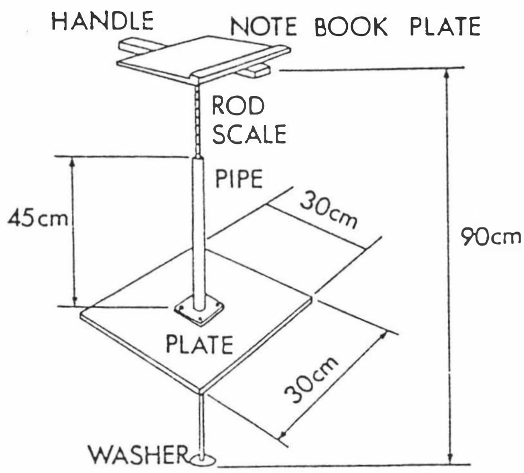
Of the different height measurements made on grazed swards, possibly the two most common are sward plate height (Holmes 1974, Michell and Large 1983) and sward surface height. Sward plate height measured using a rising plate meter or the Massey grass meter have been used simply as a management aid to control pasture condition but are used primarily for the development of local regressions relating herbage mass over large areas. The Massey grass meter (Figure 2.2) or the rising plate meter rely on taking a number of disc readings (i.e. the height) at which the disc is supported above ground level and calibrating the readings with herbage DM from a quadrat taken from the site of the mean disc reading.

On the other hand sward height, measured using an instrument like sward stick, provides a measurement of vertical height of the undisturbed surface of the sward and is used to express the height of herbage as presented to the grazing animal.

(iii) Measurement of non-vegetative attributes

Herbage mass can be estimated from one of a number of non-vegetative plant attributes for example the capacitance which has been extensively studied (Angelone *et al*, 1980; Vickery *et al*, 1980; Vickery, 1981; Meijs *et al*, 1982). Ideally the capacitance meter measures the change in capacitance caused by introducing vegetation into a capacitance system and the change in capacitance is directly proportional to herbage mass and is registered on a dial fitted to a measuring head of the meter.

**Figure 2.2: The Massey Grass Meter (Holmes 1974)**




### 2.2.1.2 Estimating Intake From Faeces Output and Digestibility

In order to obtain a normal grazing behaviour pattern and to reduce the labour requirement intake studies (described above) are usually carried out with groups of animals. Therefore the estimates do not provide absolute values for individual animals and it becomes difficult to analyse and interpret data regarding milk yields which are based on individual animals. To avoid this situation it is necessary to resort to indirect methods of estimation of individual herbage intakes. In principle they require estimates of: (a) the faecal output of the animals; and (b) the digestibility of the herbage they consumed. This is based on one basically simple precept that if the quantity (F kg) of DM (or any nutrient) excreted in the faeces of a grazing animal can be measured, and if the digestibility (D, as a decimal) of the foodstuff DM (or nutrient) is known, then intake (I kg) can be calculated from the equation given by Meijs and others (1982):- $I = F/1 - D$.

(a) <u>Faecal Output</u>

Faecal output can be estimated indirectly by oral administration of a marker or indicator such as chromium sesquioxide (chromic oxide, $Cr_2O_3$), and collection of samples of faeces either by grab sampling from the rectum or by identification of voided faeces from individual animals by means of coloured plastic particles administered with the $Cr_2O_3$ (Forbes 1986a). Extensive work on markers especially $Cr_2O_3$ has been covered (Lambourne and Reardon 1963, Langlands *et al* 1963, Christian et al 1965, Kotb and Luckey 1972, Wanyoike and Holmes 1981). Recovery of $Cr_2O_3$ for individual animals ranged from 76 to 119 percent with large variation within and between days (Carruthers and Bryant 1983). Most of the variation has been attributed to the incomplete mixing of the marker and foodstuff in the gastro-intestinal tract (Langlands 1975). Attempts have been made to improve the mixing by twice daily dosing of $Cr_2O_3$ and by dosing with paper or straw (Corbett *et al* 1960, Chamberlain and Thomas 1983). The spring driven controlled release intra-ruminal device (CRD) is a recent innovation (Laby *et al* 1984) and has been used to administer $Cr_2O_3$ in cattle. With CRD, $Cr_2O_3$ excretion reached a steady-state plateau in 5-6 days and was uniformly distributed in the faeces and diurnal variation of $Cr_2O_3$ excretion was removed (Ellis *et al* 1982).

(b) Estimating Digestibility

Once faecal output has been measured or estimated there remains the problem of estimating the digestibility of the herbage consumed. Markers such as lignin or n-alkanes, as mentioned earlier, could be used to determine digestibility. The standard method is the *in vivo* digestibility. However in a grazing experiment *in vivo* digestibility is difficult to perform, but this could be done with sheep or preferably with cattle if it was involving cattle concurrently to assess the nutritive value of the herbage consumed. An alternative would be to use *in vitro* techniques such as the one developed by Tilley and Terry (1963) or the cellulose solubility technique developed by Jones and Hayward (1975). The source of the extrusa would be from an oesophageally fistulated grazing animal.

## 2.3 NUTRIENT REQUIREMENTS OF THE DAIRY COW

The nutrient requirements of a dairy cow will be governed by stage of lactation, level of production and cow condition. The measurement of the requirement for different nutrients at different performance levels allows suitable diets to be formulated to meet these requirements. These are the amounts of nutrient which must be supplied in the diet to meet the animal's needs for maintenance of the body, and for production (lactation, reproduction and growth).

### 2.3.1 METABOLISABLE ENERGY REQUIREMENTS

The importance of energy in animal production has been established and comprehensive information has been published (ARC 1980, 1984; Scott *et al* 1980; MAFF 1984). The metabolisable energy (ME) unit is now widely adopted as the basic feeding unit in which the energy value of feeds and animal requirements are expressed.

ME of a foodstuff can be calculated with some accuracy from the digestible energy (DE) using a factor of 0.81 (Leaver 1983, MAFF 1975, 1984) i.e. ME = 0.81 DE. Various standards are based on ME with energy allowances being expressed in MJ ME/day and the nutritive value of feeds in terms of their ME content (MJ ME/day) (Bryant and Trigg 1982). The system involves the separate calculation of maintenance and production allowances which are then summed. In calculating these energy allowances one has to consider both the animal factors including liveweight, milk yield and composition, age, pregnancy and the cow's potential as well as the ability of pasture (feed) to supply the energy requirements. The various physiological demands plus that of maintenance (which is influenced by liveweight change) all change almost continuously during the lactational-reproductive cycle. With this dynamic system in which body reserves are mobilised or deposited at various stages of lactation, it is necessary to modify the ME allowances according to these changes. Annual herd requirements can be generated basing the daily or weekly allowances but taking into account the changing feeding value of the pasture with seasonal variations, replacement stock and calving-drying off dates.

The net requirement for ME is a function of how much a cow can eat (kg DM) and how much the herbage can offer depending on the initial GE and digestibility. Assuming that a cow consumes 17.5 kg of DM of pasture she will end up with 11.4 MJ/kg DM (see Table 2.1) if the diet had a value of 18.5 MJ/kg DM GE under temperate conditions (Leaver 1983). Again assuming (under a grazing situation) that a 400 kg cow was producing 20.0 kg of milk of 4.5 percent fat and losing 1.0 kg/day liveweight, then the calculation for ME requirement (in New Zealand) would be:-

ME requirement = $M_m + M_l + M_g$; where

$M_m$ = 8.3 + 0.091 W = allowance for maintenance including an activity allowance and safety margin

FCM = 0.4 MY (milk yield, kg) + 15 FY (fat yield, kg) = fat corrected milk (kg)

$M_l$ = FCM + 5.31 = requirement for milk production

$M_g$ =-28 MJ/kg loss = requirement for change in liveweight

$M_m$ = 8.3 = 0.091 = 44.7 MJ ME/day

FCM = 0.4 x 20 + 15(20 x 0.045) = 21.5 kg

$M_l$ = 21.5 x 5.31 = 114.2 MJ ME/day

$M_g$ = -1.0 x 28 = 28 MJ ME/day

ME requirement = 44.7 + 114.2 - 28 = -130.9 MJ ME/day

If ME content of pasture is 11.5 MJ ME/kg DM, required DM intake is 11.4 Kg/day (Bryant and Trigg 1982).

**Table 2.1: Example of an energy balance (Leaver 1983)**

A cow on energy balance eats 17.5 kg DM of a diet of 18.5 MJ/kg DM GE.

| | | | |
|---|---|---|---|
| GE Intake | 324 MJ | | |
| Faecal energy loss = | 81 MJ | | |
| Urinary energy loss = | 18 MJ | | |
| Methane energy loss = | 26 MJ | | |
| DE Intake = | 324 - 81 | = | 243 MJ |
| ME Intake = | 324 - (81 + 18 + 26) = 199 MJ | | |
| ME Concentration = | 199/17.5 | = | 11.4 MJ/kg DM |

### 2.3.2 PROTEIN REQUIREMENTS

Milk contains a high concentration of protein accounting for almost 300 - 400 g/litre of milk. The cow also requires protein for maintenance, for growth, for replacement of tissue protein mobilised in early lactation and for pregnancy. Requirements of cows for amino acids are met from microbes in the rumen and digested in the small intestine and from the dietary protein that is not degraded in the rumen but digested in the intestines. Therefore cow requirements for protein are expressed in terms of rumen degradable protein (RDP) required to meet the requirements of the microbes. Dietary RDP levels below this minimum will lead to reduced digestibility and voluntary food intake. Undegradable dietary protein (UDP) or bypass protein is also necessary to supply the net tissue protein requirements not met from microbial protein (Leaver 1983, ARC 1984).

Accepting that under some conditions the flow of amino acids from the rumen may not be ideal for maximum production, there are several possible ways by which the deficit may be corrected, for example, by feeding protein that is not degraded in the rumen, by feeding protected amino acids (Buttery and Foulds 1985). Despite the difficulty of being able to obtain definitive responses to individual amino acids in the lactating dairy cow, there is no doubt that increasing the protein supply at the duodenum will induce a production response (Orskov *et al* 1977, Waghorn and Barry 1987). This is particularly so if protein is the first limiting factor. Protein can increase milk yield by providing more amino acids, by increasing available energy, and by altering efficiency of utilisation of absorbed nutrients.

Microbial protein production depends on the availability of an adequate supply of energy, and RDP supply from the diet. This has been demonstrated under tropical conditions whereby supplementing cows with protein supplements had no significant responses when the energy supply was limiting (Whiteman, 1980; Cowan, 1985). A detailed schedule for quantitative requirements of dairy cattle for protein has been described by ARC (1980, 1984).

### 2.3.3 MINERAL REQUIREMENTS

More than 20 elements are essential components of the diet in that they have proven important metabolic rates in the animal. Some of these elements are shown in Table 2.2. The content of major minerals in grazed herbage varies according to soil type, soil pH and fertiliser applications as well as geographical location.

**Table 2.2 Mineral requirements of lactating cows (milk yield 20 kg/day)**

| Major minerals (g/kg DM) | | Trace minerals (mg/kg DM) | |
|---|---|---|---|
| Calcium | 3.4 | Copper | 8-11 |
| Phosphorous | 3.1 | Cobalt | 0.11 |
| Magnesium | 1.8 | Iodine | 0.5 |
| Sodium | 1.2 | Iron | 40 |
| | | Manganese | 20-25 |
| | | Zinc | 30 |
| | | Selenium | 0.03-0.05 |

Source - 'The Nutrient Requirements of Ruminant Livestock' Commonwealth Agricultural Bureaux, 1980 (Leaver 1983).

## 2.4 MANAGEMENT OF GRAZING AND LIVESTOCK

Grazing management can be described as the manipulation of feed supply and stock feed demands to economically maximise farm productivity per animal and per hectare. Good grazing management should provide a large supply of high quality herbage throughout the year at low cost, avoid physical wastage of herbage and utilise it efficiently and at the same time maintain the productive capacity of the sward. Livestock production from grazing lands is a function of soil-plant-animal interactions and this entails the integration of each of these facets into an effective management system to achieve increased livestock productivity. Being aware of changes of weather within and between seasons; changes of sward conditions and quality as well as the varying demands of the cow this is not an easy task and needs quick decisions and proper feed budgeting. It is not the intention of this study to tackle all constraints related to management of a dairy farm. However achievements towards some of these goals start from the proper choice of pasture plants for that locality; the most suitable breed of cattle and to adopt a workable breeding scheme (calving and drying off dates) and be able to manipulate stocking rates (SR), herbage allowances and grazing intervals as the pasture swards change in growth rates and quality.

### 2.4.1 PASTURE PLANTS

The decision to choose pasture species lies within the individual farmer but relies heavily on research findings within the locality in relation to environmental factors.

In temperate regions ryegrass and white clover have won the confidence of many farmers. However other species such as Matua Prairie Grass (*Bromus spp*) could be an excellent alternative for out of season production. Matua has spring and autumn peaks but is most valuable for winter growth. White clover has similar advantages by having vigorous summer growth when its companion component, ryegrass, declines in growth rate (Langer 1982, Holmes and Wilson 1984). In fact the growth patterns of ryegrass and white clover in the same sward may be regarded as complementary. If grown together the two species, Matua and ryegrass could be complementary too.

### 2.4.2 CALVING DATE AND DRYING OFF

In any pasture growing environment in which efficient milk production is required it is obvious that a system which attempts to match the changing requirements of the dairy cow throughout its lactational-reproductive cycle to the quantity and quality of feed available must be of major importance. This is the basis of the spring-calving system and for this reason the bulk of farms in this country have their calving period occurring during the late-winter-early-spring months of each year to coincide with the peak supply of herbage in spring-summer months. Lactation is a function of calving date and drying off date which demarcate the beginning and end of this cycle respectively. Lactating animals have very high demand for feed which is met by the vigorous growth of pastures in spring and summer as well as autumn. Some cows however may calve a little bit earlier and suffer from low DM intake from the lush rapid growing young pasture which is characterised by low fibre concentration. To alleviate this problem some more fibrous supplements such as silage or straw may be supplied to the lactating cows.

As the seasons change the climatic conditions become less conducive for vigorous growth. Quantity and quality also deteriorate (see Section 2.5.3.2 below). This is evident in late-autumn and winter. Sometimes the weather conditions are not favourable in summer as well, due to water moisture deficit in the soil. It is during these difficult times (late autumn or early winter) when once per day milking or drying off are advocated. Some form of supplementary feeding might be necessary.

In some temperate countries such as Britain and indeed in many tropical regions grazing is practicable only for a portion of the year ranging from about five months in the extreme north of Scotland to about nine months in the southwest of England (Holmes 1980). Similarly in the semi-humid tropical latitudes nutritious herbage for grazing is available for only 5-6 months. Therefore grazing cannot be considered in isolation. Some of the feed has to be conserved as hay or silage. This needs careful decision on the type and amount of feed to be used during winter or other times when grazing is not possible or grazing alone is not sufficient to meet the cows' requirements. How much to conserve and how much to graze depend on the growth rate and pattern of the pasture and how management manipulates SR in the long run and herbage allowance in the short term.

### 2.4.3 STOCKING RATES (SR), HERBAGE ALLOWANCE AND ROTATION TIME

#### 2.4.3.1 Stocking Rate (SR)

The interactions between grazing animals and grazed pasture are complex and important. Management therefore tries to achieve a balance between animal production objectives by feeding the herd well, maintaining the productivity of the sward by avoiding overgrazing or undergrazing and utilising herbage before it becomes stemy and senescent by use of recommended stocking rates and/or rotation time.

Stocking rate is normally expressed as a number of animals (cows) per given area (hectare or acre) for a given period. No single SR can be recommended for all localities in a country simply because the farms in each locality have slightly different capacities for pasture production. and may have different types of stock and management policies.

In New Zealand 2-3 cows per hectare has been adopted as ideal SR in many localities. SR must be based on potential productivity of pastures.

The potential herbage mass actually harvested by the grazing cow is materially influenced by the number of mouths to eat it. Unless carried out to an extreme an increase in stocking rate usually leads to an increased production per hectare but decreased production per cow. Having high SR during periods of fast growth leads to better utilisation and per hectare output, but increased competition for a limited amount of feed generally leads to reduced intake per cow. Efficiency of harvesting and utilising the available forage does not only minimise wastage by senescence and decay but keeps the sward vegetative and consequently of high nutritive value (Holmes 1980, Holmes and McMillan 1982, Barnes 1985).

The yield and botanical composition of the sward can be suddenly and substantially altered by the grazing cows. Cows defoliate selectively, graze and tread pastures, deposit excreta and disperse seeds (Watkin and Clements 1978, Curll 1982). The effects may be deleterious or beneficial to the pastures depending on the intensity (a function of SR) and frequency as well as mode of the influence exerted directly usually by changing the soil properties and microclimates of the sward.

#### 2.4.3.2 Herbage Allowance and Intensity of Grazing

Herbage Allowance, which is the amount of DM (kg) given to a cow for a period of 24 hours, can be changed from day to day depending on the pregrazing herbage mass of the sward. Swards are dynamic entities, therefore it is not possible to use one herbage allowance. The larger the pasture allowance the more the intake up to the cow's maximum voluntary intake. Herbage allowance is generally reduced at higher SR (Holmes and Wilson 1984).

As the SR increases the grazing pressure rises accordingly, the herbage allowance falls. When the grazing pressure is low and the pasture supply is plentiful animals graze selectively. Increasing or reducing herbage allowance may have beneficial consequences depending on cow requirements and sward conditions as well as soil conditions. Voluntary feed intake (as discussed in subsequent sections) may be affected by varying herbage allowance.

#### 2.4.3.3 Rotation Time

Under a conventional rotational grazing system pasture is grazed for a short period then the cows are removed for a longer period while the pasture is allowed to regrow and then the pasture is grazed again. The period between the successive grazings is called the length of rotation or grazing interval. If stock remain on a pasture for prolonged periods of time, this is known as continuous grazing or set-stocking. It is normal practice to use rotational grazing with sufficient time for regrowth. The grazing interval or length of rotation depends on the season e.g. 15-25 days in spring or 40-90 days in winter (Holmes and Wilson 1984) as growth rate slows down during the cooler months.

Regrowth of pasture swards is influenced by the frequency and intensity of previous grazings. However unlike environmental factors which also influence regrowth rates, frequency and intensity of grazing cannot easily be described in terms of optimal levels. Undoubtly this is a reflection of the interactions of frequency and intensity of grazing with environment and the resulting effect on regrowth rates (Korte and Sheath 1978, Hodgson and Maxwell 1981, Grant and King 1983).

### 2.4.4 FEED CONSERVATION

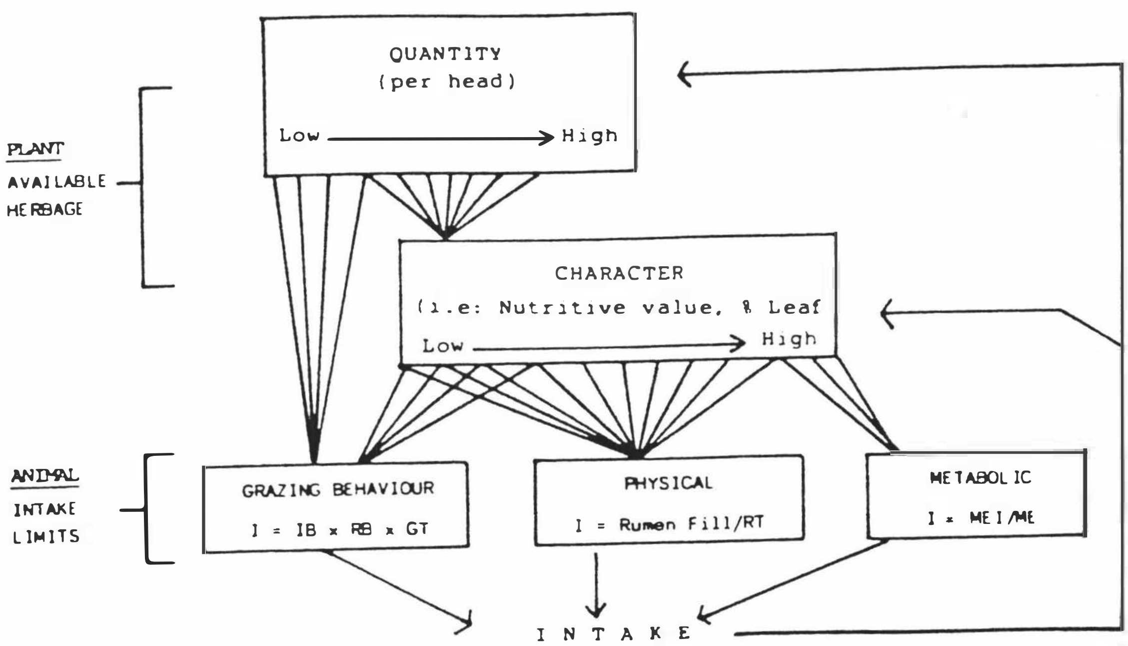
No matter how careful one is in manipulating SR's and herbage allowances, there are bound to be surpluses and deficits which have to be accommodated in the management. As feed supply exceeds cow requirements the surplus feed can be used to cope with feed shortages in early spring, dry summers and in winter.

## 2.5 VOLUNTARY FOOD INTAKE BY GRAZING COWS

The voluntary intake of food is defined as the amount eaten during a period of time when the food is offered *ad libitum* (Freer 1981). The food on offer may vary widely within and between plants and with time in sensory characteristics that affect diet selection and in density of its distribution over the grazing area. With seasonal changes, plant growth and soil and terrain variations the grazing animal is subjected to a continually changing pattern of food supply (Meijs 1981).

The potential intake of a ruminant is determined by various physiological and anatomical factors together with quality and quantity of the food on offer and the way the diet is presented to the ruminant. Therefore in a grazing situation voluntary food intake (VFI) may be influenced by a variety of sward characteristics, factors of management origin, factors of the grazing animal as well as environment such as ambient temperature, humidity, solar radiation, water availability and soil conditions. A summary of these factors which determine the grazing ruminant's potential intake are illustrated in Figure 2.3 below. The figure shows those factors which govern intake for both the penned animal (stall fed) and the extra features that the grazing animal encounters in order to achieve her nutrient demand especially energy. These include sward conditions.

**Figure 2.3 Schematic representation of factors influencing dry matter intake of ruminants, (from** Hoogendoorn, 1986).




(I = intake; IB = intake per bite; RB = rate of biting; GT = grazing time; RT = retention time; MEI = metabolizeable energy intake; ME = metabolizeable energy concentration of the diet (MJ/Kg DM) )

### 2.5.1 REGULATION OF FOOD INTAKE

Gastrointestinal factors and factors associated with the nutritional and physical properties of foods are interrelated in their effects in intake (Baile and Della-Fera 1988). The most important factor limiting VFI in ruminant feeding on coarse forages is rumen fill or physical capacity (Campling 1970, Bines 1971. The bulky nature of diets (pasture) eaten by grazing animals often results in rumen being filled to capacity before enough food has been consumed to meet the nutrient requirements (especially for the high yielders) for maximum production. However, rumen fill is not the only factor governing intake in all situations. Conrad, Pratt and Hibbs (1964) suggested that physical factors were important in forages having a DM digestibility of less than 66% but that with higher quality feeds, metabolic or physiological factors become important. Experimental evidence has shown that the regulation of intake is biphasic, implying that food intake is restricted physically primarily due to rumen fill but later in the process of eating by the nutrient (metabolic) demands of the animal (Conrad et al 1964; Bull *et al* 1976; Forbes 1983, 1986a).

### 2.5.2 INITIATION AND TERMINATION OF MEALS AND LONG TERM CONTROL OF INTAKE

The brain is obviously the integrator of all the relevant information and the controller of the act of eating (Forbes 1986b). The initiation of eating seems to occur in response to a relative deficit of energy to supply requirements (Forbes 1983). During the physical phase of intake regulation rumen fill is thought to restrict intake by physical stimulation of stretch receptors in the rumen wall. The degree of physical "fill" is monitored by tension and epithelial receptors which respond to increased distension of the gut (Leek 1986; Gill et al 1988). Such receptors have been identified electrophysiologically by Leek and Harding (1975).

When no restrictions are placed on intake feeding is stopped in response to one or more satiety signals indicating that the animal's energy requirements have been met. These signals apparently originate in the gastrointestinal tract, hepatic portal system, adipose tissue, peripheral blood and cerebrospinal fluid and are transmitted to the central nervous system in particular ventromedial and ventrolateral hypothalamus to inform as to the nutritional state of the body (Bell 1971; Annison *et al* 1982; Forbes 1983; Baldwin 1985; De Jong 1986). Such signals can be metabolites such as the major volatile fatty acids (VFA) (acetate, propionate and butyrate) and/or hormones. Acetate the most abundant (VFA) in the rumen causes a depression in food intake when infused in the rumen but not effective with similar amounts if infused into any blood vessel. The greater the quantity of food (especially roughage) eaten, the greater the amount of acetate produced and the stronger the satiating signal from the rumen receptors (Forbes 1986b). Of the brain-gut hormones cholecystokinin (CCK) is the most likely to play a role in the control of feeding (McLaughlin 1982; De Jong 1986); Bombesin (McLaughlin 1982), insulin, pancreatic glucagon and growth hormone (Forbes 1980) are known to be physiological regulators of intake in ruminants. In the long term there are feedbacks from bodyfat reserves which modulate the short term control of feed intake to provide long term stability of body weight and composition (Baumgardt 1970; Forbes 1983). De Jong (1986) suggests that plasma insulin, which is a predictor of adiposity, is involved in the control of long term food intake and body weight. In monogastrics considerable evidence supports this hypothesis but in ruminants the negative feedback from fat on feeding merits further research (Forbes 1983; De Jong 1986).

### 2.5.3 PHYSICAL FACTORS LIMITING INTAKE

Whether or not rumen fill limits intake depends on the equilibrium between degree of fill, stretch of the rumen and rate of disappearance of digesta from the rumen, both by absorption and passage (Van Soest 1982, Forbes 1986a). Other factors that may restrict intake independently of physical capacity include protein deficiencies in the feed ingested, acidic conditions in the rumen, food palatability and toxic substances such as excess amount of selenium, water deprivation and possibility feeding frequency (Forbes 1986a). Both feed characteristics and animals factors are important.

#### 2.5.3.1 Animal Factors

The principal determinant of rumen capacity is the size of the animal; thus when food of a relatively low digestibility is given to a number of animals, intake is broadly related to liveweight ($LW^{1.0}$) (Bines 1971). In part at least, this is determined by the size of the abdominal cavity which appears to be limited in the extent to which it can stretch.

The effect of gut capacity on intake has clearly been demonstrated by displacement of the gastrointestinal space with inert materials such as balloons, sponges or plastic ribbons (Baile and Forbes 1974; Van Soest 1982).

Gut capacity may further be limited by displacement of the abdominal cavity into which the rumen expands during eating. This can be caused by fat deposits within and around the abdominal cavity or foetal displacement during late pregnancy (Bines, 1971; Bines *et al* 1969). Thus, in early pregnancy, roughage intake can be maintained or even increased and the abdomen can be seen to become more distended. Eventually, however, further distension is apparently not possible, foetal enlargement within the abdominal cavity occurs at the expense of rumen capacity and food intake is often reduced. Bines *et al* (1969) observed that thin cows ate more hay than fat cows with no difference in the mean retention time of digesta in the rumen. An effect of fatness on intake independent of rumen fill was also demonstrated.

In the lactating cow it is possible that the increased demand for nutrients can be met in part by what has been termed a hypertrophy of the alimentary canal, thus permitting an increased food intake (Bines 1971).

#### 2.5.3.2 Food Characteristics

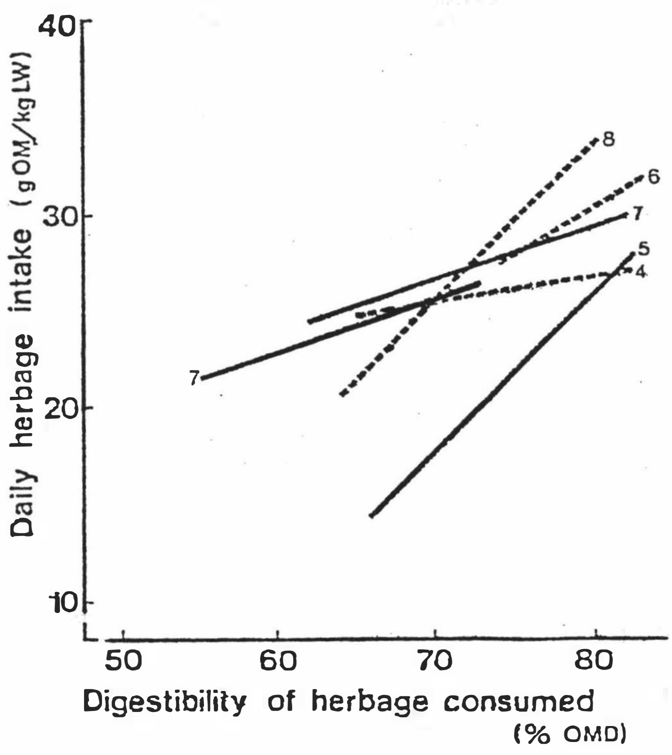
The chemical and physical properties of forage influence both the quantity of forage consumed and he nutrients which become available for metabolism in the grazing ruminant (Beever and Siddons 1986). The major nutritional factor influencing intake is digestibility of the pasture consumed such that as digestibility increases so does intake (Hodgson 1977; Poppi *et al* 1987).

(a) Digestibility

Digestibility is determined by the same factors which determine rumen fill including indigestibility, rate of digestion and retention time. Retention time of digesta in the rumen refers to digesta disappearance by digestion and passage (Poppi *et al* 1987).

It has been mentioned above that with fibrous diets, intake is limited by rumen fill (or the quantity of material in the rumen) and the rate of passage through the rumen (Campling 1970). At high levels of digestibility voluntary intake is controlled more by the energy requirements of the animal and less by the above physical factors, and that intake levels off at digestibilities above 65% (Conrad *et al* 1964; Baumgardt 1970). However, experiments with cattle grazing temperate swards (reviewed by Hodgson 1977) have shown a significant and constant rate of increase in herbage intake over the full range of digestibility values studied, ie 55-85% (see Figure 2.4) with no evidence of the curvilinear response reported for pen studies by Conrad et al (1964) and Balch and Campling (1969). Similar results, with no evidence of curvilinear response, have been reviewed by Minson (1982) for tropical grasses and legumes.

**Figure 2.4: The relationship between digestibility of the diet selected (OMD%) and the herbage intake (g OM/kg LW) of lactating cows (- - -) and growing calves (_______) (From Hodgson, 1977)**



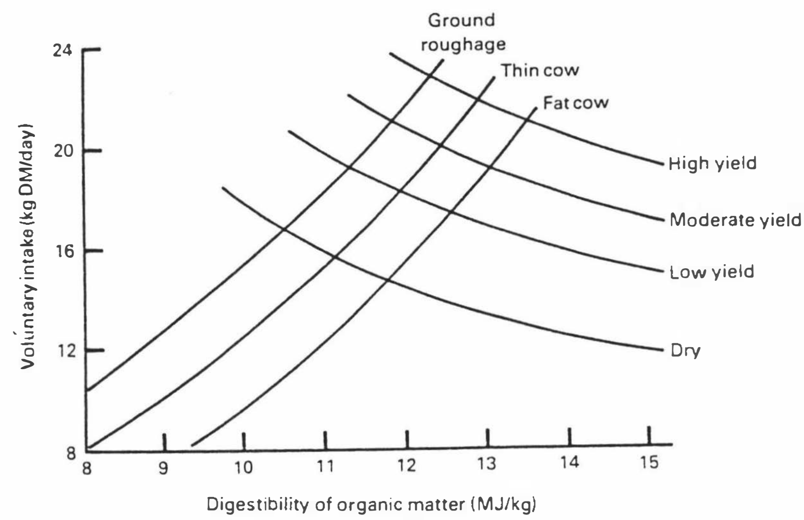
References as indicated on the figure are as follows:
4 = Corbett (1963); 5 = Hodgson (1968); 6 = Holmes (1972); 7 = Rodriguez Capriles (1974); 8 = Stehr (1976). For references 4, 5, 7 and 8 equations quoted by authors (modified where necessary to common LW base); for reference 6, equation calculated from author's data. No equations differed significantly from linearity.

The different intake/digestibility relationship obtained may be explained in two ways. The early work by Conrad *et al* (1964) and Balch and Campling (1969) cited by Minson 1982 was carried out with mature, non-productive animals unlike the more recent work with lactating cows or growing animals in a grazing situation in which sward characteristics interact with each other and with digestibility. The grazing situation may produce intake responses dissimilar to those obtained in pen trials (Hodgson 1977). Secondly the early findings were with mixed roughage/concentrate diets (Conrad *et al* 1964; Baumgardt 1970, see Figure 2.5) and do not apply to herbage diets where linear responses in intake have been shown up to 82% digestibility as reviewed by Leaver (1985) or beyond (Hodgson 1977) and as illustrated in Figure 2.4. The reasons for the discrepancy between roughage/concentrate and herbage diets is that at any particular digestibility there is a large variation in voluntary intake between feeds. Diets containing concentrates have higher intake characteristics than herbages or roughages. Non-physical factors limiting intake therefore come into operation at lower digestibility values with concentrate-based diets (Leaver 1985) and as illustrated in Figure 2.5. Figure 2.5 is a summary of the interactions between the metabolic and physical controls of feeding (discussed in section 2.5.1 above) such that the relationship between VFI and food quality is biphasic, with a positive slope for poor-and moderate- quality foods and a negative slope for good-quality foods (Forbes 1986b).

(b)Physical and Chemical Composition of Forage

The physical and chemical properties of a feed can affect food intake by influencing digestibility rate of disappearance from the gastrointestinal

**Figure 2.5: Relationship between voluntary food intake and digestible energy yield of feeds for cows of various milk yields and physical characteristics. (from Forbes 1986b).**




tract and termination of feeding due to gut fill or influencing the nature and amount of metabolites produced from the diet.

(i) Physical Differences Between Leaf and Stem

Physical differences exist between leaf and stem of the same plant. Leaf is consumed in greater quantities than stem of similar DM digestibility (Minson 1982, 1983). Where there are large quality differences between leaves and stems in a pasture animals prefer to eat leaf. The higher intake of the leaf fraction has been association with shorter time the leaf fraction is retained in the rumen compared with the stem fraction.

The leaf fraction has a larger surface area per unit weight than the stem fraction and this might allow more rapid digestion. The most probable reason, however, for the longer retention time of the stem fraction in the rumen is the higher proportion of large particles in masticated stem than in masticated leaf because of the greater resistance of stem to physical breakdown (Minson 1982).

(ii) Density

Feeds of higher density such as ground, chopped or pelleted forages will be associated with higher intakes than feeds of lower density such as longer forages (ARC, 1980; Minson, 1982; Van Soest, 1982).

(iii) Cell Wall Content (CWC) and Maturity

The cell wall content of a diet (largely the structural carbohydrates) has recently been established as the primary feed characteristics responsible for the effect of rumen fill on intake. Cell contents (largely soluble carbohydrates and proteins) are rapidly digested whereas cell walls, the fibrous fraction of lignin, cellulose and hemicellulose are slowly digested (Van Soest 1982; Poppi *et al* 1987). Differences in intakes between species of varieties of pasture plants at the same level of digestibility have been shown and attributed to differences in crude fibre percentage related to CWC. Advancing maturity is accompanied by changes in chemical composition of grasses (Holmes 1980). During maturation of herbage the proportion of CWC progressively increases but, more importantly the potential digestibility and rate of digestion of the material decreases (Holmes 1980; Van Soest 1982).

(iv) Differences Between Pasture Plants

Legumes are eaten in greater quantities than grasses of similar energy digestibility (Crampton 1957, Ulyatt *et al* 1977). This appears to be due to a shorter retention time and a higher packing density of legumes in the rumen (Thornton and Minson 1973) resulting from their lower CWC and ratio of hemicellulose than grasses (Osbourn 1980). Generally legumes are more digestible than grasses and give better responses in terms of fattening (Rattray and Joyce 1974; Gibb and Treacher 1983) and milk production (Thomson 1984; Thomson *et al* 1985 (see Table 2.3); Cammell *et al* 1986). Mean yields and composition of milk shown in Table 2.3 show the different responses of ryegrass and white clover in terms of milk yield, milk composition, milk energy output and the flow of organic matter and non-ammonia nitrogen (NAN) to the duodenum (Thomson *et al* 1985). Differences with other legumes and grasses have been investigated (Corbett 1980). Compared with grasses legumes contain higher proportion of protein, organic acids and minerals but less structural fibre and water soluble carbohydrates. Similarly within grasses there are differences in intake between species and between varieties within species at the same digestibility (Wilson 1967; Ulyatt 1971; Leaver 1985).

But differences in nutritive value among ryegrass varieties did not appear to be a significant factor in determining intake of nutrients (Brookes and Lancashire 1979). The amount of AA and NAN absorbed from the small intestine is higher from legumes than grasses and these may provide ample supply of essential precursors for protein synthesis and a source of energy (glucogenic precursor) as well as stimulate mobilisation of body energy reserves for milk production (Brookes 1982).

**Table 2.3 Mean yields (kg/d) and composition (g/kg) of milk with the yield of milk constituents (kg/d) from 20 Friesian cows grazing either perennial ryegrass or white clover ad lib. from weeks 4 to 18 of lactation, (from Thomson *et al* 1985).**

| | Perennial Ryegrass | White Clover | s.e.m. | Significance |
|---|---|---|---|---|
| Gross milk yield | 22.2 | 25.0 | 0.81 | * |
| Milk composition | | | | |
| Fat | 41.5 | 38.9 | 0.67 | * |
| Protein | 29.8 | 30.9 | 0.69 | NS |
| Lactose | 49.4 | 49.8 | 0.38 | NS |
| Yield of constituents | | | | |
| Fat | 0.92 | 0.97 | 0.038 | NS |
| Protein | 0.66 | 0.77 | 0.025 | ** |
| Lactose | 1.09 | 1.25 | 0.048 | * |
| Solids corrected | 22.1 | 24.4 | 0.86 | NS |

Significance levels: NS, Not significant; *P<0.05; **P<0.01; s.e.m. Standard error of mean.

(v) Seasonal Effects on Nutritive Value of Pasture

Early cut grass (spring pasture) is utilised much more efficiently for liveweight gain than late cut grass (autumn pasture) of similar digestibility (Corbett et al 1963). A possible cause for higher feeding value of spring herbage is the greater proportion of protein that may escape rumen degradation due to fast rate of passage. Spring pasture also has higher amounts of soluble carbohydrates which might be important in maintaining microbial growth and the ultimate provision of AA for absorption from the small intestines (Waghorn and Barry 1987). As the season progresses, the dead material in the sward increases (Le Du *et al* 1981).

(vi) Selective Grazing

Cattle eat very little dead material provided green leaf is available. This selective grazing results in a lower intake per bite (IB), rate of intake and daily DM intake (Leaver 1985). The degree to which cows can select herbage of a higher digestibility than the average of that on offer will depend on the amount on offer and the botanical composition (Chenost and Demorquilly 1982). The herbage selected may be 3-10% higher in digestibility than the average of that on offer (Le Du *et al* 1981). The digestibility and more particularly the intake characteristics of the herbage are thus very influential on the performance of grazing cows.

(vii) Protein and Other Dietary Components

The efficiency with which ME is utilised for milk production and other activities is influenced by or associated with protein. For example insufficient amounts of protein and of certain vitamins and mineral elements in the diet, along with an imbalanced assortment of absorbed amino acids, reduce the efficiency with which ME is utilised by dairy cows for production (Reid *et al* 1980).

While protein deficiency may pose a serious problem under tropical pastures during the dry season this is not the case in temperate latitudes. However, with highly fermentable lush grass in the temperates, in early spring protein deficiency may manifest especially in high producing dairy cows in early lactation. When the crude protein content of the pasture falls below 6-8% appetite is depressed and pasture intake is reduced (Minson 1982). The situation is worsened with low energy diets.

Adequate levels of dietary sulphur, sodium and phosphorus as well as trace minerals are also required in recommended amounts (Underwood 1981) to promote intake and production (Minson 1982).

### 2.5.4 ENERGY DEMANDS CONTROLLING INTAKE

The overall regulation of VFI in ruminants embraces many physiological processes and several factors may act as important determinants of the level achieved (Weston 1982). In theory, an upper limit to VFI is set by the ruminant's potential energy demand which depends upon interactions among genotype, physiological state (liveweight, body condition, pregnancy and lactation), energy required to graze and chew herbage and energy expenditure in countering climatic effects (Freer 1981).

#### 2.5.4.1 Physiological Factors

For feeds of high digestibility when rumen fill is no longer a limiting factor, intake is proportional to metabolic liveweight ($LW^{0.75}$) for an animal of given physiological state (Conrad et al 1964). The power 0.75 is conventionally used to calculate cow metabolic LW and gives reasonable agreement in most cases. However, the power at which LW is related to intake can vary with such factors as age, sex and breed of the animal. Thus, intake is dependent on the metabolic size of the animal, its production and diet digestibility (Conrad et al, 1964, Bines 1971; Forbes 1971).

(i) Body Composition (Fatness)

Fat deposition depresses intake in most species (Forbes 1986a). Pasture intake decreases (by 10%) in cattle of higher fat content (Weston 1982) and Bines *et al* (1969) found thin cows ate more of a 20% high concentrate diet than fat cows thus demonstrating an effect of fatness which was independent of gut capacity. It was concluded that intake regulation was mainly metabolic in nature and flexible in its operation, permitting the thin cows to eat more of the diet than the fat cows. The higher intake of concentrates by the thin animals was attributed to their greater capacity for lipogenesis (Forbes 1986a).

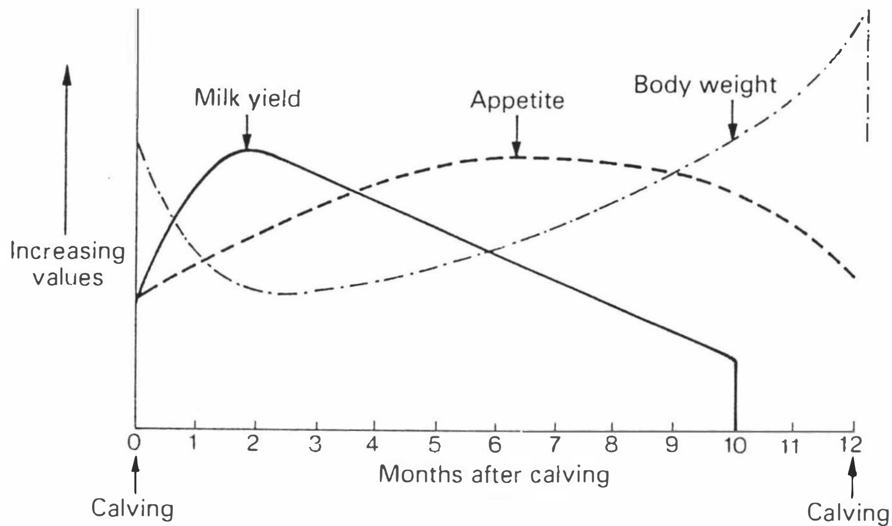
(ii) Pregnancy

During pregnancy the volume and nutrient demand of the conceptus progressively increase and the dam's endocrine status changes. These major physical and metabolic changes affect voluntary food intake (Forbes 1970, 1971). The demands of the conceptus will increase nutrient requirements and therefore voluntary intake. However, paradoxically, this effect on intake might well be counteracted by the physical effect of the uterus (Forbes 1986b) and possibly hormonal changes, and most likely oestrogen secretions (Forbes 1980, 1986c), which would tend to depress intake. The upward displacement of the ventral wall of the rumen in late pregnancy has been shown to be associated with a reduction in rumen digests volume and voluntary food consumption (Forbes 1970, 1971) and accordingly Forbes 1980) has suggested that pressure on the rumen, or abdominal wall distension, might modulate intake.

(iii) Lactation

The ruminant, like the monogastric animal, achieves its highest voluntary intake during pregnancy, the maximum energy intake by highly productive dairy cows being 70% above that of growing steers (Baumgardt, 1970). VFI increases promptly after parturition, reaching a maximum after a variable time, thereafter remaining fairly steady, or declining slowly (Weston 1982). Lactating cows eat 35-50% more than non-lactating cows of the same weight and on the same diet (ARC 1980) depending of stage of lactation. Comparisons of lactating and non-pregnant, non-lactating animals have shown voluntary consumption of fresh pasture herbage to be increased by 50% in lactating dairy cows (Hutton 1963).

**Figure 2.6: Changes in milk yield, body weight and appetite of dairy cows during lactation (from Mepham 1987).**




After parturition there is increased abdominal capacity as a result of the disappearance of the conceptus. Therefore a rapid increase in voluntary intake would be expected in the first few days of lactation, if the major limit to intake is physical. Intake lags behind milk yield despite the immediate increase in space for the rumen reaching a peak several weeks after peak milk yield (Figure 2.6) (Freer 1981, Forbes 1986c). High yielding cows therefore are in negative energy balance for about 10 weeks postpartum (Bauman and Elliot 1983; Mepham 1987; see also Figure 2.6). In order to meet the increased nutrient demand of the lactating mammary gland, it is necessary to mobilise body fat and protein. This emphasises the importance of adequate nutrition pre-calving and subsequent target body weight or body condition at calving (Rogers et al 1979; Broster and Thomas 1981; Haresign 1981; Macmillan et al 1982). Reasons for this lag of voluntary intake is unclear. Although postparturient fat cows eat less than thinner ones, a physical explanation is not sufficient to account for the slow changes which are observed, nor is the rate at which rumen hypertrophy and/or hyperplasia can occur. Some of the suggestions for this phenomenon include time taken for the rate of metabolism in the rumen and tissue to adapt to the increased nutrient demand after calving, time taken for the mobilisation of abdominal fat deposits prepartum to allow maximum rumen fill (Bines 1976); an influence of endocrine factors on intake in early lactation (Forbes 1970, 1986c) and the release of free fatty acids adipose tissue after calving corresponding to a low intake (Journet and Remond 1976).

A physical limitation on voluntary intake has been suggested with long roughage especially in early lactation when energy demands of lactation are relatively high (Forbes 1970). Peak intake is reached earlier after calving with diets of higher metabolisability (Journet and Remond 1976).

During early lactation the intake of energy from grazed pasture may be lower than the cow's total capacity to utilise energy for maintenance and milk production. Consequently it might be necessary to feed high energy diets, but even so recourse to the withdraw of body reserves is inevitable if milk production is to attain its genetically determined limits. As a result the cow loses an appreciable amount of body weight over this critical period (Haresign 1981; Bauman and Elliot 1983; Mepham 1987).

As lactation proceeds the voluntary food intake continues to increase and the partition of nutrients between the udder and body tissue moves towards the latter. The net result of this is that milk yield declines and body weight, due to repletion of body reserves, begins to increase (see Figure 2.6).

#### 2.5.4.2 Genetic Potential of the Cow

Animals of high genetic merit produce more milk, have greater voluntary intake and use more of their body reserves in early lactation than those of low merit (ARC 1980; Bryant and Trigg 1981; Davey et al 1983; Bauman et al 1985). The significance of cow quality as assessed by breeding index (BI) in both cow and farm production has been studied at Massey University (Davey et al 1983) and Ruakura Agricultural Station (Bryant and Trigg 1981). The results in these studies indicate that cows of high genetic potential (HBI) have higher food intake than those with low genetic potential (LBI).

## 2.6 HERBAGE ALLOWANCE AND SWARD CONDITIONS INFLUENCING INTAKE AND GRAZING BEHAVIOUR IN CATTLE

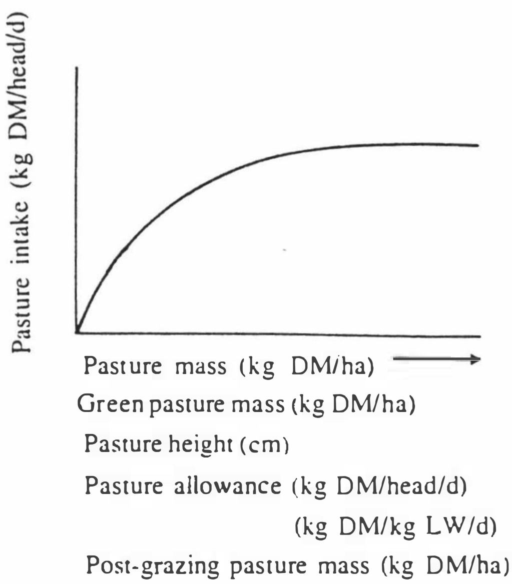
Herbage allowance (kg DM/cow/day) is probably the most important single factor, in New Zealand, responsible for the differences in production per animals between farms, between years, and between stocking rates (Rattray and Jagusch, 1978). Herbage allowance is, in effect, the quantity of feed made available to each cow and not suprisingly it has a major effect on the amount of feed consumed by each cow (Holmes 1987). Other non-nutritional factors that may influence intake and animal production include pregrazing herbage mass, herbage height and bulk density.

### 2.6.1 HERBAGE ALLOWANCE ON INTAKE AND PERFORMANCE

Herbage allowance is the weight of herbage available per animal or per unit of animal liveweight (g/kg) per day (Hodgson, 1975, 1979). An alternative term is its reciprocal, grazing pressure, the number of animals of a specified class per unit weight of herbage at a point in time (Hodgson 1979).

The relationship between daily herbage intake and herbage allowance is essentially asymptotic (Hodgson 1977) such that intake declines at a progressively faster rate when the daily allowance is reduced below a critical level (Combellas and Hodgson, 1979; Le Du *et al*, 1979; Holmes, 1987). (See Figure 2.7). Cows offered a relatively small herbage allowance will attempt to consume all of the herbage, but this will become progressively more difficult with time, as the remaining pasture becomes shorter and more difficult to bite and ingest (Holmes 1987) and this relationship may differ on different swards depencing on botantical composition and morphology of the sward components.
The effect of herbage allowance and intake has been demonstrated for cows grazing in New Zealand (Bryant, 1980; Glassey *et al*, 1980) and some of these studies have been reviewed by Holmes and MacMillan (1982, see Table 2.4 below).

**Figure 2.7: The relationship of pasture intake to various pasture characteristics and methods of pasture allocation. (Adapted from Poppi et al** 1987).




In all trials mentioned above including those conducted in New Zealand, the herbage allowances were offered as one break for a 24-hour period. When the herbage available is measured to ground level, herbage intake is often about maximal when the herbage allowance is twice the herbage intake as demonstrated by Combellas and Hodgson (1979).

**Table 2.4: Values for Herbage Allowance, Intake and Residual Yields for Experiments with Dairy Cows (from Holmes and Macmillan, 1982).**

| | Herbage Allowance (kg DM/cow) | Herbage Intake (kg DM/cow) | Post-Grazing Residual Yield (kg DM/ha) |
|---|---|---|---|
| Lactating Cows | | | |
| Bryant 1980 | | | |
| Paspalum, ryegrass clover, 3,100 kg DM/ha before grazing | 52 | 12.5 | 2,390 |
| | 40 | 11.6 | 2,250 |
| | 26 | 9.4 | 2,010 |
| | 13 | 9.1 | 920 |
| Glassey *et al* (1980) | | | |
| Ryegrass, clover. 2,700 kg DM/ha before grazing. | 53 | 16.3 | 1,850 |
| | 33 | 14.3 | 1,550 |
| | 14 | 9.6 | 750 |
| Bryant (1978) | | | |
| Luceme. 4,200 kg DM/ha before grazing. | 38 | 16.0 | 2,420 |
| | 28 | 16.0 | 1,790 |
| | 18 | 12.1 | 1,380 |
| Dry Cows | | | |
| Holmes and McClenaghen (1980) 2,850 to 4,020 kg DM/ha before grazing. | 19 | 11.9 | 1,220 |
| | 13 | 9.6 | 815 |
| | 9 | 7.3 | 500 |
| | 6 | 5.1 | 260 |

In New Zealand some studies have shown herbage intake and milk yield responses to much higher allowances of herbage. For example Bryant (1980) used herbage allowances up to about 50 kg DM/cow/day at three stages of lactation. The relationship was linear in early lactation even through allowance was 4 to 5 times DM intake, but curvilinearity increased as lactation progressed. Linear relationship was also observed in Australian by Stockdale (1985) using lactating dairy cows on irrigated pasture contrary to the normally accepted curvilinear relationship (Greenhalgh *et al* 1966; Hodgson, 1977) between DMI and herbage allowance.

Increases in herbage allowance are generally associated with increases in milk production per cow (Holmes 1987) depending on the physiological status and genetic potential of the animal. Therefore high daily yields of milk per cow require generous herbage allowances (Bryant 1980) and intake of high yielding dairy cows is more sensitive to restrictions in herbage allowance than that of low yielding dairy cows (Combellas 1977 quoted by Stakelum 1986). But high levels of hergabe allowance are associated with lenient grazing resulting in large amounts of post-grazing herbage mass uneaten (Bryant 1981) and may cause only small increases in milk production, but large increases in liveweight (Holmes 1987). Similar responses are also observed with non-lactating cows in change in condition score; higher allowances contribute relatively higher gains (or lower losses) in condition score e.g. Holmes and McClenaghan (1980). Lenient grazing may affect both quality and quantity of the herbage consu med apart from decreasing efficiency of grazing and of feed utilisation (Hodgson, 1979; Holmes, Davey and Grainger, 1981).

The effects of herbage allowance on milk composition have generally been small (Leaver 1985). At low allowances milk fat content may increase (Le Du *et al* 1981), possibly owing to the reduced milk yield level and to the consumption of more dead leaf and stem material in the base of the sward.

### 2.6.2 SWARD CHARACTERISTICS INFLUENCING HERBAGE INTAKE

Non nutritional characteristics of the sward, associated primarily with variations in the mass of herbage and its distribution within the foliage canopy may restrict the intake of grazing animals (Hodgson 1977). Of importance in this study are herbage mass, herbage height, and herbage density, all of which may affect grazing behaviour and herbage intake (Hodgson 1982a).

#### 2.6.2.1 Herbage Mass

Differences in pre-grazing herbage mass (kg DM/ha) influence intake per bite (IB) and rate of biting (RB). IB decreases sharply as herbage mass declines in both sheep and cattle on temperate and tropical swards (Allden and Whittaker, 1970; Stobbs, 1973a; Chacon and Stobbs, 1976;

Jamieson and Hodgson, 1979a, b; Zoby and Holmes, 1983; Forbes and Hodgson, 1985). Increases in RB often occur when IB is depressed and this increase has been observed as herbage mass declines, but this is seldom of a magnitude suffiecient to avoid a reduction in DM intake (Hodgsom 1981). Daily herbage intake usually increases at a progressively decreasing rate as the available herbage mass per unit area increases and declines at an increasing rate below a critical mass (see Figure 2.7 above). For cattle grazing temperate pastures determinations of the critical mass below which DM intake declines have been reported over a two-fold range 1100 –2800 kg DM/ha) (Hodgson 1977). Increases inintake associated with increases in pre-grazing herbage mass have also been reported by Hodgson (1975); Jamieson and Hodgson (1979b), Zoby and Holmes (1983), Forbes and Hodgson (1975) and Stockdale (1985). The increased intake with increased herbage mass probably reflects the more favourable spatial distribution of the herbage in relation to ease of perhension by the grazing animal.

In most studies herbage mass, rather than herbage allowance, appeared to be less important in rotational grazing systems than in continuous grazing systems (Holmes 1987). However when high pre-grazing herbage mass is associated with decreased digestibility (Holmes 1987) or nutritive value (Hodgson 1986) then this characteristic becomes important in both systems.

Decreases in intake have been observed contrary to studies already mentioned in association with increase in pre-grazing herbage mass e.g. Reardon (1977), at both intermittent grazing and continuous grazing systems. These conflicting results could be explained in part by the interaction between herbage mass and herbage allowance as suggested by Combellas and Hodgson (1979), Jamieson and Hodgson (1979a) and Meijs (1981).

**2.6.2.2 Herbage Height**

Close positive correlation is usually observed between sward height and herbage mass and tend to influence intake in the same way (Hodgson 1981, 1982a). Intake usually increases with increasing sward surface height in temperate swards (Allden and Whittaker, 1970; Hodgson 1982a). Herbage height may influence both bite size and intake but it is naive to think that bite size and intake will be determined by height alone (Poppi *et al* 1987). The increase in intake with increasing sward height in temperate swards is due mainly to increased IB (Hodgson 1982a) although decreased intake may be observed in particularly long herbage (Waite *et al* 1951; Hodgson 1982a) and many tropical swards.

Herbage intake usually increases at a progressively decreasing rate with increases in sward surface height (see Figure 2.7). If the extended height of the sward is measured then the relationship between sward height and intake may be quadratic, with intake declining on either side of the optimum extended height (Hughes 1983).

The critical post-grazing heights below which intake and milk production are reduced have been estimated as 8-10 cm for rotational and 6-8 cm for continuous stocking systems (Le Du and Hutchinson 1982). Herbage intake is depressed by 10-15% if dairy cows on rotational systems are forced to graze down to a residual sward height of 5 cm and on continuous stocking a sward height of 5 cm will reduce intakes by 20% (Emst *et al* 1980).

**2.6.2.3 Bulk Density and Leaf/Stem Ratio**

Bulk density and height of herbage are often negatively correlated. The effect of bulk density on intake has not been studied extensively. However Mott (1982) has suggested that since tiller density of temperate grasses is greater than that of many cultivated tropical grasses, bulk density of forage presented to grazing animals may be greater for temperate grasses, facilitating their prehension rate and increasing their bite size (Mott 1982). The vertical distribution of foliage exerts the major influence on ingestive behaviour in temperate swards (Hodgson 1982a, b) whereas in tropical swards variables associated with leaf density and leaf/stem ratio are of dominant importance (Stobbs 1975; Hodgson, 1982b; Mott, 1982).

### 2.6.3 GRAZING BEHAVIOUR AND COW PERFORMANCE

Many of the metabolic and physical controls of food intake which apply to housed animals also apply to grazing animals and these controls have been discussed in previous sections and have been reviewed extensively (e.g. Baile and Della-Fera, 1981 and Forbes, 1986a, b). However, in the grazing animal there are many non-nutritional factors which influence herbage intake such as sward characteristics (section 2.6), environmental factors such as ambient temperature and the animal's ability to modify its grazing behaviour.

Metabolic and physical stimuli are clearly the dominant factors controlling herbage intake in housed animals (Freer 1981) but behavioural inhibitions assume greater importance under grazing conditions (Hodgson 1985).

Allden and Whittaker (1970) following Allden (1962) provided a framework for much work on grazing behaviour when they suggested that herbage intake (I) was the product of the weight of herbage consumed per bite (IB), the rate of biting (RB) and the time spent grazing (GT). Thus:

$$I = IB \times RB \times GT$$

Each component can be influenced by plant and animal variables. The primary facilitatory stimulus is probably energy demand, although other nutrients may also be involved (Hodgson 1986). Energy demand will be influenced by the various factors discussed in previous sections. Inhibitory stimuli include physical satiety (as discussed above) and behavioural inhibition. Physical satiety is likely to be more important than metabolic limits in grazing animals, since feed intake increases linearly with digestibility up to about 80% (Hodgson 1977), which is the upper limit experienced during grazing. Behavioural inhibition reflects the ability of the animal to modify its grazing behaviour in response to sward conditions, environment and factors imposed by the farmer (Arnold, 1981; Hodgson, 1982a, 1986; Kilgour, 1983).The normal pattern of grazing behaviour consists of periods of grazing ruminating and resting. This study will concentrate on the components of ingestive behaviour particularly grazing time, despite the fact that other components of normal grazing (e.g. camping, rumination, loafing, excretion) may directly affect aspects of grazing activity (Hancock, 1951, 1953; Dulphy, Remond and Theriez, 1980; Arnold, 1981, 1985).

**2.6.3.1 Ingestive Behaviour of Grazing Cattle**

Detailed description of the typical activity of grazing has been given by Hodgson (1982b, 1986) which includes the prehension of herbage and the manipulation of gathering and swallowing the feed.

In theory, I of grass could be calculated by multiplying the GT x IB x RB. However the time spent grazing, the frequency of biting and the weight prehended per bite are difficult to measure absolutely. As the error-free state is not easy to achieve it is probably prudent to think of measurements of ingestive behaviour as a means of explaining observed effects on herbage intake rather than as a means of estimating intake itself (Hodgson and Maxwell, 1982; Hodgson 1982b).

**2.6.3.2 Bite Size (IB)**

Intake per bite, IB is the variable most directly influenced by the physical characteristics of the sward canopy and has been shown to be positively related to herbage mass (Allden and Whittaker, 1970; Jamieson and Hodgson, 1979b; Hodgson, 1986) and sward height (Allden and Whittaker, 1970; Hodgson, 1981, 1986) in temperate swards.

Direct measurement of bite size usually involves the use of oesphageally fistulated animals (Stobbs 1973a) by total collection of extrusa in a leakproof bag. A record is made of all bites taken during collection (Forbes 1988). Bite size thus is the product of the dry weight of the extrusa collected divided by the number of bites taken.

Intake per bite shows the greatest experimental variation across treatments and usually exerts a dominant influence upon daily herbage intake (Hodgson 1982b) with rate of biting and grazing time being compensatory variables. Selective grazing is a major cause for declines in bite size (Hodgson and Maxwell, 1981; Forbes, 1988).

#### 2.6.3.3 Rate of Biting (RB)

The rate of biting, RB, usually tends to increase with declining IB, but the rate of increase is seldom fast enough to prevent an associated decline in the short-term rate of intake (IB x RB) (Allden and Whittaker, 1970; Chacon and Stobbs, 1976; Hodgson, 1981, 1985; Forbes and Hodgson, 1985). This decline in intake appears to be due primarily to a reduction in the number of manipulative jaw movements required on shorter swards and a consequent increase in the ration biting:manipulative movements (Hodgson 1985).

Methods of measuring rate of biting have been described by Hodgson (1982b).

#### 2.6.3.4 Grazing Time

The most readily apparent adaptive response is the increase in grazing time GT which usually occurs when the rate of intake declines (Freer, 1981; Hodgson, 1985). This compensation, however, is seldom adequate to prevent a fall in daily intake once the short-term rate of intake starts to decline and grazing time may itself fall on particularly short swards (Hodgson, 1985, 1986) thus contributing further to declining intake.

Estimates of GT may be derived from the continuous monitoring of activity or by using an interval sampling technique. The former is likely to be the more accurate, but is difficult to carry out unless automatic equipment is available. Although recording intervals of 5-10 minutes are commonly preferred, no significant differences between estimates of grazing time is derived from observations at intervals of 1, 15, 30 and 45 minutes (Hafez and Lindsay, 1965; Hodgson, 1982b). Observation is normally carried out over a 24-hour period on several occasions.

When observing a group or groups of animals, it is preferable to record activity of each animal individually rather than to categorise the numbers of animals engaged in particular activities. The former procedure ensures a better base of making statistical comparisons, and for relating behaviour to other variables such as herbage intake on an individual basis (Hodgson 1982b)

#### 2.6.3.5 Grazing Patterns

A cow's day is divided into clearly defined periods of grazing, ruminating (chewing the cud), idling and rest (Hancock 1950, 1953; Arnold 1981, 1985; Hodgson, 1982b; Kilgour and Dalton, 1983). Ruminants graze mainly during daylight and have two main meals: after dawn and before twilight (Dulphy *et al* 1980). There is a complementary relationship between the time spent grazing (eating) and ruminating such that the total time spent chewing per unit of feed intake is similar for any one feed, rapid ingestion is followed by a longer ruminating time (Campling and Morgan 1981)

Grazing studies have shown that cows normally spend 8-10 hours a day to satisfy their apetites. A maximum of 36,000 bites may be achieved during grazing (Kilgour and Dalton 1983). However the circadian pattern of grazing and time spent grazing may change in response to sward characteristics, nutrient demand of the ruminant and external stimuli including weather conditions and the presence of other animals (Dulphy *et al*, 1980; Arnold, 1981, 1985; Hodgson, 1982b). These changes in grazing patterns may be seasonal or diurnal (Phillips and Leaver, 1986). Under intensive conditions, and with a restricted food allowance, animals will feed whenever food is offered. With an ad libitum supply circadian patterns develop (Arnold 1985). Extremes in size of pasture, in either direction, cause excessive walking. Walking and loafing are increased in large pasture areas because of the novelty of the environment (Arave and Albright 1981). Hancock (1953) observed that cattle, given time, will adapt their grazing habits to meet changing environmental conditions.

## 2.7 EFFECT OF FREQUENCY OF FEEDING UPON FOOD UTILIZATION BY RUMINANTS

Manipulation of the diet composition and meal frequency can produce different patterns of energy utilization from the same amount of digestible energy in the lactating cow. The effects are particularly apparent with diets containing large amounts of concentrates, which result in milk fat depression (Campbell and Merilan 1961; Burt and Dunton 1967; Orskov 1975; Gibson 1981, 1984; Sutton 1981, 1985; Sutton et al 1985 1986) in housed dairy cows.

In a grazing situation it is not possible to manipulate directly the diet composition. However manipulation of the amount of herbage at pasture is facilitated by changing stocking rates or herbage allowances to match the herd's nutrient requirements as previously mentioned. The traditional system of feeding dairy cows in New Zealand, and elsewhere, is to offer sufficient pasture that will provide the required dry matter intake for a 24 hour period coupled with rotational grazing. This may involve subdividing the pasture area (paddock) to provide the required herbage allowance. Increasing the stocking rate in the long run or reducing the area (herbage allowance) have both metabolic and economic consequences: efficient grazing and efficient feed utilization may be achieved by forcing the cows to eat a high proportion of the pasture allotted. Although this may result in high output per hectare it may lead to reduced intake, liveweight gain and milk production per cow.

Frequent feeding at pasture can be achieved by further pasture rationing, ie giving the herbage allowance in more than one break per day. Few experiments have been conducted to evaluate the effects of feeding frequency on cow performance at pasture. Notable studies are those done by Hancock (1954a) and Flux and Patchell (1955).

With pen fed animals the major aim of feeding concentrates has been to increase liveweight gains or milk production by use of high energy diets, eg grains and their by-products. The difficulty, however, has been combining a high level of milk production with the maintenance of a satisfactory milk fat content or normal rumen fermentation. The fall in fat content or the now well known "low milk fat syndrome" has triggered a series of experiments since the late 1940's (McDonald 1948). With grazing animals the major aims have been better utilization of pasture or increasing herbage intake and as a means of controlling bloat.

The two situations will be reviewed separately.

### 2.7.1 CONCENTRATE BASED DIETS

Diurnal patterns of several parameters in rumen fluid are affected by feeding frequency (Annison and Bicherstaffe 1974; Gibson 1981, 1984; Gill and Castle 1983; Sniffen and Robinson 1984; Robinson and Sniffen 1985). Many workers have demonstrated the diurnal response to once daily feeding in cattle and sheep of rumen ammonia N concentration (McDonald 1948) of pH (Kaufmann, Hagemeister and Dirksen 1980; Thomas and Rook 1981) of VFA (Kaufmann, Hagemeister and Dirksen 1980; Sutton 1980 , 1981; Sutton et al 1985, 1986) of osmolality (Phillip et al 1980) and of phosphate (Sniffen and Robinson 1984). The findings suggest that feeding infrequently will lead to increased diurnal variation in many rumen fluid characteristics. It is logical to assume that reduction of this variation is desirable and will lead to improved cattle performance (Sniffen and Robinson 1984; Sutton 1985). Of importance here in milk production or weight gain is the energy as volatile fatty acids (VFA) in terms of quantity and proportion between acetic acid plus butyric acid and propionic acid. There is now evidence that when low-roughage diets are fed, to ruminants, increasing the frequency of feeding reduces milk fat depression by altering aspects of VFA production in the rumen (Sutton, Hart and Broster 1982). Not all studies had similar results. The responses between growing sheep or cattle and lactating cows have been varied.

#### 2.7.1.1 The effects of feeding frequency on the growth and efficiency of food utilization

Burt and Dunton (1967) reviewed the data available and found six experiments with growing cattle and sheep where a positive gain response to increased feeding was achieved, eg Gordon and Tribe (1952) for sheep and Campbell et al (1963) for growing cattle. They also identified 12 experiments where no response was achieved, eg Campbell et al (1963). Similar results were observed by Horton and Nelson (1961) dealing with dairy heifers fed four to eight times a day. Horton (1964) again found no positive response when working with growing Jersey and Holstein heifers.

It seemed clear that when positive responses were achieved it was due to an increased level of feed intake, and usually when the infrequent feeding treatment was once daily.

Subsequently (Gibson 1981) reviewed the published data on the effects of feeding frequency on cattle. He identified five experiments where positive gain response to increased feeding frequency were obtained, but also reported eight others where no response was found. However, he reported that increasing the frequency of feeding from once or twice to four times daily increased average weight gain and efficiency of growth by approximately 16 and 18% respectively. In terms of animal production it was concluded that cattle should be fed at least four times daily to ensure maximum feed utilization for growth. Some of these good experiments reviewed include those conducted by Clark and Keener (1962) and Fletcher et al (1968). Graham (1967) in a comprehensive experiment, demonstrated appreciable improvements in both digestive and metabolic efficiency when adult sheep were fed eight times daily rather than once.

More recently Adams et al (1983) noted increased food intake and fatter carcasses in lambs which were fed ad libitum with fresh food offered four times per day rather than once per day.

Because increased feeding frequency sometimes improves the growth rate and efficiency of food utilization of growing cattle and sheep it might be expected that more substantial improvements might be expected for dairy cattle.

#### 2.7.1.2 Feeding frequency for lactating cows

Campbell and Merilan (1961) noted an increased milk output of 1.6 kg per day when feeding frequency was increased from two to four times daily. However Burt and Dunton (1976) found no improvement in production from increased feeding frequency. Production in these cows ranged from as low as 5.8 to only 17.7 kg milk/day (Sniffen and Robinson 1984), so they can hardly be considered high producing animals where substantial benefits due to improved nutrient availability might be expected. Similar results were noted by Thomas and Kelly (1976) who showed that milk secretion was not affected by increased feeding frequency, but the cows were producing only 9-12 kg milk per day.

Recently Gill and Castle (1983) also found no improvement from increased feeding frequency in production. Lactating and dry cows, given an average of 7 kg concentrates per day, did not change their silage intake or feeding pattern, irrespective of whether the concentrate was given 2 or 22 times per day (Gill and Castle 1983). Even more recently Gibson (1984) analysing the published results concluded that cows producing milk of commercially acceptable milk concentrations were unlikely to benefit from increased feeding frequency. However when milk concentration is depressed, more frequent feeding does reduce the depression (Gibson 1984). There was no evidence that more frequent feeding influenced milk protein concentration. From the foregoing it seems to be only minimal experimental evidence to suggest that increased daily feeding of a blended ration will lead to increased milk production in dairy cows. Clearly there is a conflict between experiments. Many workers have attempted to explain the underlying reasons for positive or negative responses to frequent feeding. There is no one best approach to these conflicts. High yielding cows need large amounts of energy. Large amounts of energy can be increased by increasing levels of feeding by giving generous herbage allowances. But as previously discussed gut capacity may limit intake if the diet is predominantly roughage. Therefore, if high-energy intakes are to be achieved, it is necessary to overcome the physical limitations to intake associated with diets consisting predominantly of roughage. This can be done by adding to the ration a highly digestible source of energy, usually starchy concentrate. However, such manipulations of diet, for the lactating dairy cow, have repercussions on rumen fermentation and milk fat content, on energy partition between milk and body tissue (Broster, Sutton and Bines 1979; Kaufmann, Hagemeister and Dirksen 1980; Sutton 1981) and on incidence of digestive disturbances (Dirksen 1970; Broster, Sutton and Bines 1979).

(i) Rumen fermentation and proportion of volatile fatty acids

Restricted amounts of cereal grains (concentrates) usually increase the total intake of digestible energy. However rapid consumption of large amounts of readily fermentable carbohydrates such as maize or barley results in two important consequences - shift from high amount of acetic and butyric acids to high proportion of propionic acid caused by selective proliferation of acid producing microorganisms including Lactobacilli. This results in a drop in pH. The shift and magnitude of the effects depends on the concentrate: forage ratio of the diet, the amount of the concentrate at a given time, and the type of cereal given to the cow (Dirksen 1970; Orskov 1975; Kaufmann, Hagemeister and Dirksen 1980; Thomas and Rook 1981; Baldwin and Allison 1983; Sniffen and Robinson 1984). Rapid consumption of concentrates characterises parlor feeding, during the two milkings, which will disturb rumen fermentation. It is during this period (after feeding) that rumen pH is depressed and depending upon the degree of depression, could result in reduced activity of rumen cellulolytic and proteolytic bacteria (Sniffen and Robinson 1984). Cellulolytic bacteria are very sensitive to the rumen pH. A rumen pH of less than 6.2 will seriously inhibit their growth (Orskov 1982). Inactive bacteria cannot make sue of even the best substrate (Sutton et al 1985). Certainly, reduction in rumen pH fluctuation has been suggested as one of the major reasons for increased feeding frequency (Kaufmann 1976. See also figure 2.8). Figure 2.8 illustrates how to avoid drastic fall in pH by frequent feeding a certain level of concentrates - the interrupted line represents twice daily feeding frequency whereas the continuous one six times daily. As the pH fluctuates with twice daily feeding, the supply of VFA to the body also fluctuates widely over the day and this almost certainly adds to the very considerable metabolic stress of the high-producing dairy cow at peak lactation (Sutton et al 1985). In the same way an increase in the ratio of the molar proportions of acetate: propionate in the rumen VFA's is also influenced (Broster, Sutton and Bines 1979; Sutton 1981,

1985) which is proportional to the amount of concentrate added or the amount of roughage reduced in the ration. (Kirchgessner, Muller and Schwarz 1982; Sutton, Hart and Broster 1982; see also Table 2.5).

**Figure 2.8: Typical variation of pH value in the forestomachs regarding different feeding frequencies using concentrates (From Kaufmann, Hagemeister and Dirksen 1980)**

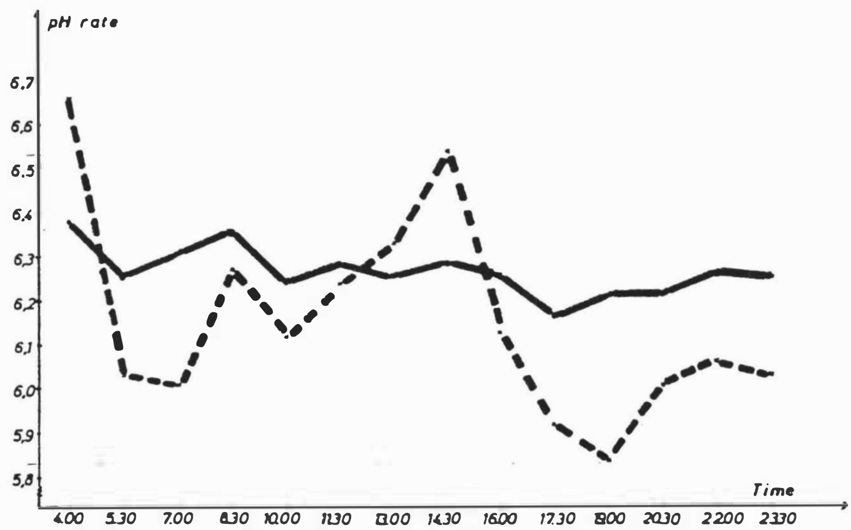



**Table 2.5: Effects of feeding frequency on energy utilisation, rumen volatile fatty acids (VFA) and plasma insulin (From Sutton, Hart and Broster, 1982)**

| Expt 1: % concentrates: | 70 | | 90 | | SEM[1] |
|---|---|---|---|---|---|
| meals/d: | 2 | 6 | 2 | 6 | |
| Energy digestibility | 0.72 | 0.75 | 0.76 | 0.78 | $0.007^{DF}$ |
| DE intake (MJ/d) | 181 | 190 | 181 | 187 | $1.8^{F}$ |
| Milk Energy (MJ/d)[2] | 55.8 | 62.1 | 51.7 | 57.3 | 3.36 |
| Rumen VFA (mol/100 mol) | | | | | |
| Acetic | 64.5 | 65.3 | 52.1 | 56.1 | $1.75^{D}$ |
| Propionic | 17.2 | 16.3 | 28.9 | 27.5 | $2.07^{D}$ |
| N-butyric | 12.8 | 13.8 | 11.4 | 10.7 | 1.04 |
| (Ac + Bu)/Pr | 4.5 | 4.9 | 2.2 | 2.6 | $0.29^{D}$ |
| Plasma insulin (μU/ml) | 10.9 | 10.1 | 27.8 | 14.4 | $2.23^{DF}$ |

1 Superscripts indicate significant (at least $P<0.05$) main diet (D) or frequency (F) effects.

2 Equation 1 in Tyrrell & Reid (1965).

(ii) Type of concentrate and nutrient utilization

There is some evidence that a different response occurs when ground maize is used instead of rolled barley (Orskov 1975; Sutton 1981; Sutton *et al* 1980). A depression in milk fat is decreased with rolled barley. So it appears now that milk fat depression induced by low roughage diets is certainly closely related to the type of rumen fermentation. It is associated with an increased supply of glucogenic precursors in the form of propionate or of starch (especially with maize) in the duodenum and a decrease of acetate and butyrate since these acids are the main precursors for the *de novo* synthesis of short and medium chain fatty acids in the udder. However, the repartioning of nutrients towards adipose tissue and the elevated plasma insulin levels that have been observed with 'high-propionate' diets have lent support to the view that the dietary effect may be hormonally mediated (Sutton 1981; Sutton, Hart and Broster 1982; Sutton *et al* 1986; see also Table 2.5). The glucose formed from propionate or absorbed from the duodenum stimulates secretion of blood insulin.

### 2.7.2 GRAZED PASTURE

The early studies of feeding frequency and probably the only ones were conducted in New Zealand to investigate the prevention of bloat and observe grazing behaviour (Hancock 1954a) and assess ways of promoting efficient utilization of pasture and control bloat (Flux and Patchell 1955).

Hancock (1954a) used lactating dairy cows giving them liberal amounts of pasture under a rotational grazing system. Pastures contained a high proportion of clover (30-40% by eye estimation). The duration of the four trials was too short to measure possible effects on milk yield (Hancock 1954a). Only the first two trials are reported here as they were involved in frequency of feeding termed "break feeding" describing a system in which the daily area of pasture was given in more than one allocation.

In Experiment 1,a (Exp 1,a) the control cows were given their daily allowance at 6.30 am (after milking) while the area of the experimental cows was divided into two equal parts, one of which was given at 4.15 am (before the morning milking) and the other at 2.30 pm (before the evening milking). Grazing behaviour was observed on three occasions. The trial lasted for 17 days. Back grazing was allowed.

In Experiment 1,b (Exp 1,b) five breaks were used after assessing the slight effect with two breaks. While the control group was offered their 24 hour break at 6.00 am, the experimental group at 4.00 am, 9.00 am, 11.45 am, 2.30 pm and 4.30 pm. Back grazing was allowed. Grazing behaviour was observed on two days. The trial lasted for 17 days.

In Exp 1,a the results revealed the difference between groups in the average grazing times were small, for all three days together (Hancock 1954a). Incidence of bloat in the two groups was similar.

With five breaks a day in Exp 1,b, grazing and ruminating times were depressed by approximately half an hour each, and increased the idling time proportionately. This regime of feeding altered the normal grazing pattern, so as to cause sharp peaks of grazing immediately following the offering of new breaks (see Arnold 1981).

Bloat incidence was lowered to some extent by the offering of five breaks a day but not significantly enough to warrant adoption as a means of controlling bloat in cattle.

Experiment 2 had "break feeding" with restrictions of grazing area. This arrangement restricted the amount of feed allowed to eat daily and in so doing to prevent cows from consuming too much food at any one time, but also forcing them to graze harder and unselectively over the whole of their daily allowance. The trial lasted for eight days. Animals were observed for behaviour for four days. Forcing the cows to graze closely under this regime proved relatively difficult, especially in the beginning of the experiment, when the cows were reluctant to graze even the first breaks cleanly. The pasture used in this trial was white clover dominant (50-60% clover).

The average daily stocking rate of the frequent feeding group was over twice as great (214 cow/hectare) as that of the control group (104 cow/hectare). The grazing and ruminating times were not only short but cows were reluctant to graze in a normal, persistent manner (Hancock 1954a). It was suggested that the low grazing times observed with the frequent feeding group were partly due to the height and density of the sward which facilitated optimal herbage ingestion. However, there was little doubt that the cows seemed very rapidly to lose the desire to graze.

Bloat incidence was similar for both groups during the entire trial. As a general conclusion, the results showed that irrespective of number of breaks, frequent grazing (feeding) with or without restriction gave no effect control of bloat. Cows were able to alter their normal diurnal patterns of behaviour to accommodate the changes imposed by management. Inability to predict this adaptation made it difficult to advise in the management of grazing herds (Hancock 1954; Arave and Albright 1981).

The experiment by Flux and Patchell (1955) compared different systems of break feeding on milk production using spring calvers adopting two breaks for the experimental group. Cows were milked twice a day and yields of milk showed no significant difference between cows grazing pasture when fed one break per 24 hours period from those obtained when they were given two breaks per day. The cows were allowed about the same amount of feed under the two different systems (Flux and Patchell 1955; see also Table 2.6 below).

# PLATES

A HERBAGE MASS AFTER 22 HOURS OF GRAZING FOR I BREAK GROUP (CONTROL) IN PERIOD II

B HERBAGE MASS AFTER 22 HOURS OF GRAZING FOR 4 BREAK GROUP (EXPERIMENTAL) IN PERIOD II

# Chapter 3

# METHODS AND MATERIALS

## 3.1 AIMS OF THE EXPERIMENT

1. The main aim of the experiment was to compare herbage intake and milk production by dairy cows given all pasture in one break or in four breaks per day at a common herbage allowance. The allowance given was either a moderate quantity of 30 kg DM per cow per day during the first period of the experiment or a high quantity of 40 kg DM per cow per day during period two.

2. To observe the grazing behaviour of dairy cows at either one break or four breaks of a common herbage allowance in the second part of the experiment.

One of the aims in the original experimental design was to compare the effects of two levels of herbage allowance (low, 20 kg DM per cow per day; and moderate, 30 kg DM per cow per day) in relation to milk production. The design, a randomised 2 x 2 factorial, was abandoned due to lack of space required to run four experimental groups concurrently.

## 3.2 EXPERIMENTAL ENVIRONMENT

The trial reported in this study was conducted in two parts during spring (October-November) 1986 at the Dairy Cattle Research Unit, Massey University, Palmerston North. The Unit, run as a seasonal supply dairy operation, maintains a dairy herd of about 120 milking cows plus their replacements.

The herd consists of monozygous twins (Friesians, Jerseys and Friesian/Jersey crosses) which account for approximately half of the milking herd. The remaining cows are Friesians of either high or low breeding index (HBI or LBI), having BI's of approximately 126 and 100 respectively.
The farm area is 48 ha divided into 54 paddocks. Surplus spring/summer pasture is stored as silage, with hay requirements being purchased locally.

Pastures are mainly a mixture of perennial ryegrass (*Lolium spp*) and white clover (*Trifolium repens*) with small amounts of prairie grass (*Bromus uniloides*), cocksfoot (*Dactylis glomerata*) and red clover (*Trifoluim pratense*). All pastures are topdressed annually with approximately 375 kg/ha of 15 percent potassic superphosphate and approximately 100 kg/ha of nitrogenous fertiliser (urea) biannually in spring and autumn. During the experimental periods pregrazed herbage mass ranged from 2300 - 2500 kg DM/ha.

The Unit is situated on a heavy clay soil - Tokomaru silt loam - a soil which consists of 15-30 cm layer of heavy silt above a mottled clay loam. Serious pugging problems may arise in some paddocks especially in wet seasons and with high stocking rates.

## 3.3 WEATHER

Meteorological data for October and November 1986 are presented in Appendix 3.1. The data was collected at DSIR Grasslands Division, approximately 1 km to the north east of the Dairy Cattle Research Unit.

## 3.4 OUTLINE OF THE EXPERIMENT

### 3.4.1 STATISTICAL DESIGN

The experimental design was a simple completely randomised trial involving one type of treatment at two periods.

A total of twenty four spring calving, high producing cows from both the HBI and LBI herds were used. The treatment imposed was feeding frequency. There were two levels of feeding frequency designated as one break (1B) and four breaks (4B) (Refer to Figure 3.1 below for experimental area layout).

**Table 3.1: Treatment combinations and time sequence of the feeding frequency trial**

| Time | | Treatment Group/ Numbers of Cows | | Common Daily Herbage Allowance |
|---|---|---|---|---|
| **Period** | **Week** | **1 Break** | **4 breaks** | **kg DM/cow/day** |
| I | 1-3 | 12 cows | 12 cows | 30 |
| II | 4-5 | 8 cows | 8 cows | 40 |

Each group or experiment unit in period I was offered herbage allowance intended to provide 30 kg DM/cow/day which was an equivalent to 6.5 kg DM/100 kg liveweight. In period II a higher allowance was allocated to provide 40 kg DM/cow/day, which was an equivalent to 8 kg DM/100 kg liveweight. The treatment combinations and time sequence of the experiment are shown in Table 3.2 above.

### 3.4.2 COW SELECTION AND QUALITY

Twenty four mature Friesian cows were available from the HBI and LBI (high producing) herd. From the 24, cows were allocated at random to either one break (1B) or four breaks (4B) and used for part one of the experiment designated as period I. At the end of period I, eight cows were selected from each treatment group to continue on that treatment but at a higher allowance as shown in Table 3.1 above. The remaining four cows from each treatment were returned to the main herd.

Table 3.2 shows some of the characteristics of the cows used in the treatment groups.

**Table 3.2: Age, Liveweight, Body Condition Score, Milk Fat Yield and Calving Dates of Dairy Cows Allocated to the Two Treatments at the Start of Each Period**

(a) Period I

| | 1 Break | | 4 Breaks | |
|---|---|---|---|---|
| | Mean | sdx | Mean | sdx |
| Number of Cows | 12 | | 12 | |
| Age (Years) | 7.2 | 0.66 | 7.3 | 0.63 |
| Mean Calving Date | 19 August | | 21 August | |
| Lactation Days | 46 | 3.6 | 45 | 3.6 |
| Liveweight (kg) | 462 | 17 | 460 | 19 |
| Body Condition Score | 4.67 | 0.16 | 4.57 | 0.28 |
| Milk Fat Yield (kg) | 1.02 | 0.04 | 1.06 | 0.03 |

(b) Period II

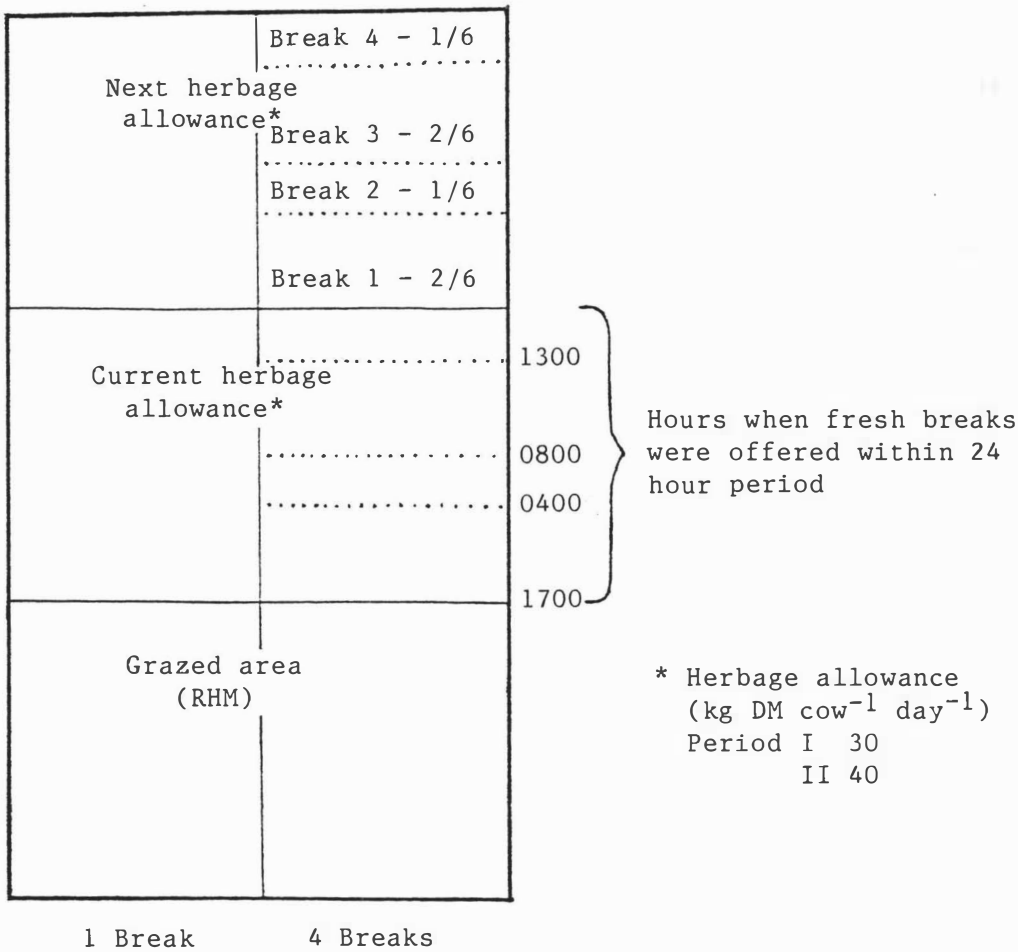
| | 1 Break | | 4 Breaks | |
|---|---|---|---|---|
| | Mean | sdx | Mean | sdx |
| Number of Cows | 8 | | 8 | |
| Age (Years) | 7.5 | 0.71 | 7.4 | 0.82 |
| Mean Calving Date | 13 August | | 21 August | |
| Lactation Days | 70 | 4 | 66 | 5.4 |
| Liveweight (kg) | 498 | 22 | 487 | 22 |
| Body Condition Score | 4.79 | 0.4 | 4.76 | 0.8 |
| Milk Fat Yield (kg) | 0.90 | 0.03 | 0.91 | 0.03 |

The cows calved between 27 July and 11 September with a mean calving Date of 23 August 1986. At the beginning of the experiment cows were 45±4 days in lactation on the average.

### 3.4.3 FEEDING LEVEL AND ALLOCATION OF FEED

A total of 13 paddocks were used for the entire experiment, 8 paddocks were available for the first part and 5 paddocks for the second part of the experiment. Each paddock lasted for 2 to 3 days depending on the pregrazed herbage mass available as well as the level of feeding. Cows were rotationally grazed. The two treatment groups grazed on separate halves of each paddock separated longitudinally by a temporary electric fence.

**Figure 3.1 Layout of grazing area and allocation of feed for 72 hours**




Both groups received the same allowance and area of pasture each day. But the control group received their fresh pasture in one area, designated one break, whereas for the treatment group, designated four breaks, the daily allowance and area were divided into 4 areas or breaks by electric fences. The grazing area layout is depicted in Figure 3.1. The figure illustrates the direction of the cows' movement, feed allocation and the proportion of feed contributed by individual breaks within a period of 72 hours. It can be observed in the Figure that breaks 1 and 3 in the 4B treatment contributed 2/3 of the total daily allowance whereas breaks 2 and 4 in the same treatment contributed 1/3 of the feed on offer. This feeding regime was adopted bearing in mind that major grazing periods begin near dawn and recur in late afternoon ending close to sunset (Arnold 1981, 1985. Hodgson 1982b). However it is also established that major peaks of grazing arise after dawn and before sunset and little night grazing is done by cattle in temperate regions. Therefore 2/3 of the daily allocation was offered to coincide with the two major peaks.

### 3.4.4 EXPERIMENTAL PERIOD

The entire experiment took 35 days. Period I which lasted for 21 days started on 4th October to 25th October 1986. Period II which took 14 days commenced on 25th October and terminated on 7th November 1986.

## 3.5 MANAGEMENT OF PADDOCKS AND EXPERIMENTAL ANIMALS

### 3.5.1 MANAGEMENT OF PADDOCKS

About 18 hours prior to entering a new sward the earmarked paddock was temporarily divided into two halves and the halves randomly assigned to the two treatments. The paddock halves were then further fenced using electric wires to demarcate the appropriate grazing sections (allowances) or breaks as shown in Figure 3.1.

### 3.5.2 MANAGEMENT OF EXPERIMENTAL ANIMALS

Before the commencement of the trial the experimental cows were grazed with the main milking herd at a generous herbage allowance.

During the experimental period the experimental animals were managed in separate groups according to their designated groups. For the one break group, cows were offered their daily herbage allowance as one 24 hour break after the afternoon milking. In the treatment (4B) group the four breaks were offered at 1700 hours, after the afternoon milking, 0400 hours, 0800 hour, after the morning milking, and 1300 hours. This arrangement applied to both periods. A backfence was used to restrict the animals access to the previous day's grazing.

The experimental herd was milked in a walk through milking shed at about 0700 hours and 1600 hours, spending approximately 2 hours each day away from their paddocks.

Fresh water was supplied by large troughs *ad libitum* for all cows in the paddock and at the milking shed.

At the end of each milking each cow's teats were sprayed with a recommended antiseptic to control the incidence of mastitis. After the afternoon milking and prior to fresh pasture break, all cows were drenched with Bloatenz (Economics Lab. NZ Ltd) as a prophylactic treatment for bloat. All cows were in good health throughout the experimental period. At the end of the experiment all animals were returned to the main herd.

For ease of management and individual attention, cows were adequately identified either by coloured necklaces as marks for treatment groups or eartags for individual identification.

## 3.6 ESTIMATION OF HERBAGE YIELD AND FEEDING VALUE OF FEED

### 3.6.1 HERBAGE MASS BEFORE AND AFTER GRAZING (kg DM/ha)

Daily measurements of herbage mass were made before and after grazing for all treatments in both periods of the trial. This was done by using the herbage cutting technique described by Meijs (1981). Five quadrats were cut to ground level on every paddock plot before and after grazing and DM yield determined. The quadrats were taken randomly on a diagonal line across each plot. Cutting was facilitated by a portable shearing handpiece. The quadrat was an open-ended rectangle (25 x 75 cm). Herbage cut from each plot was bulked, washed to remove soil and manure contamination, oven-dried at 85°C for 24-36 hours and then weighed. Herbage allowance or residual herbage mass (RHM) kg DM/ha were calculated using this information.

### 3.6.2 DAILY HERBAGE ALLOWANCE, INTAKE AND DEGREE OF DEFOLIATION

Daily herbage allowance as defined by Hodgson (1979) was calculated by determining the herbage mass (HM) (kg DM/ha) and dividing this HM by the number of cows to graze. Imposed herbage allowances (HA) for period I and period II were 30 and 40 (kg DM/cow/day) respectively. Assuming that a paddock with an area of 0.8 ha had 2400 kg DM/ha as HM, this paddock would have supported 24 cows (12 for each treatment group) for 2.5 days or would have supported 16 cows (8 for each treatment group) for 3 days at imposed herbage allowances of 32 and 40 kg DM/cow/day respectively. Thus:

$$\text{Moderate allowance:} \quad \frac{2400 \times 0.8}{24 \times 2.5} = 32 \text{ kg DM/cow/day}$$

$$\text{High allowance:} \quad \frac{2400 \times 0.8}{16 \times 3} = 40 \text{ kg DM/cow/day}$$

However in this study time was not fixed but allowances were imposed. Therefore the exercise involved calculating the time these cows would have spent in one paddock or section. For example, using the same paddock the 16 animals in the second part of the experiment would have grazed for 3 days at an imposed allowance of 40 kg DM/cow/day:

$$\frac{2400 \times 0.8}{16 \times 40} = 3 \text{ days}$$

Results of these calculations are presented in Chapter Four.

Residual herbage mass or post-grazing HM, as described by Hodgson (1979) and Thomas (1980), was measured by the same technique as for pre-grazing herbage mass.

Average daily DM intake per cow was then calculated as the difference between the pasture dry matter offered and RHM, divided by the number of cows grazing that area. It was assumed that the herbage which disappeared during grazing had been consumed by the grazing animals and no correction was made for herbage growth during the grazing period since this was unlikely to have been significant (Meijs *et al* 1982) for the present short intervals of 2-3 days.

### 3.6.3 HERBAGE ORGANIC MATTER CONCENTRATION, ORGANIC MATTER, DIGESTIBILITY, NITROGEN CONCENTRATION AND NITROGEN DIGESTIBILITY

Subsamples were obtained from the unwashed bulked herbage which had been cut from each plot of each paddock and bulked by paddock for the determination of concentration of organic matter (OM), nitrogen and digestibility of the same. The samples were packed in plastic bags and preserved in the freezer awaiting the chemical analyses.

## 3.7 MEASUREMENT OF ANIMAL PRODUCTION RESPONSES

### 3.7.1 MILK YIELD AND MILK COMPOSITION

Milk yield was measured by the use of sampling meters (True-test Distributors Ltd), which sampled a proportion of the milk flow of each cow. Afternoon and morning yields were obtained by adding the recording made at consecutive afternoon and morning milkings respectively. By adding together these consecutive afternoon and morning milkings, the daily yields of milk were generated.

During period I milk yields were recorded on 2 or 3 days each week, whereas during period II yields were recorded on 3 or 4 days each week. For 3 weeks before the experiment the milk yield and milk composition of each cow was recorded. The mean values obtained in this period were used as covariates in the analysis of the effects of feeding frequency on cow performance.

Daily yields of milk and milk components were also recorded once per week from the end of the experiment until end of November 1986. The mean values obtained in this period are presented in graphical forms in Chapter Four as unadjusted means.

Weekly averages of milkfat, milk protein and lactose were determined by calculating the individual afternoon and morning measurements separately as well as calculating the daily measurements of these yields for each cow during the experimental period.

Milk samples were analysed to determine the concentration of milk fat, milk protein and lactose. Milk composition was determined by the Milko-Scan 104 A/B (A/S N Foss Electric, Denmark). These data were subjected to repeated measurement analysis of covariance (see Section 3.9.1).

### 3.7.2 COW LIVEWEIGHT AND BODY CONDITION SCORE

Liveweights (LW) and body condition score (CS) were determined at the beginning and at the end of each experimental period by single observations. At each recording, cows were weighed (unfasted) at 0800 hours and assigned CS by using the score system reported by Scott and Smeaton (1980) by one independent scorer.

## 3.8 GRAZING BEHAVIOUR MEASUREMENTS IN PERIOD TWO

Grazing behaviour (GB) of cows was observed during period II of the trial. The major behaviour parameters were recorded at 15-20 minute intervals by a team of observers over a 24 hour period on two separate occasions, starting at 1700 hours. This was immediately after fresh breaks of pasture had been offered to the cows.

Attention was concentrated upon grazing time (GT) as one important component of the ingestive behaviour although other components of normal grazing behaviour were also observed. These included ruminating time (RT), walking, camping (lying and sleeping) or just standing as important items that could affect aspects of grazing activity (Arnold 1981, 1985).

During daytime hours, approximately 0530 - 1900 hours, the observer could monitor most activities for each individual cow from a protected tractor at a distance (10 - 20 metres). However during the hours of darkness the observer had to walk quietly among the animals and recorded the number of cows engaged in each activity (e.g. 4 cows grazing, 4 cows lying) rather than the activity of each cow. The cows were accustomed to human presence and did not appear to be disturbed by either the observer or the presence of the tractor.

The total amount of time spent at each activity during daytime by each cow was taken as the number of times that activity was recorded multiplied by 15 or 20 minutes as the case applied. The procedure during darkness was not similar and recording was confined to grazing, standing or lying and these activities were calculated by multiplying by 15 or 20 minutes and by the number of cows that were engaged in that particular activity eg 3 cows grazing x 20 and 5 cows lying x 20 etc.

Only grazing time (in minutes) was analysed by grouping data as day and total grazing time for the individual days and for the two days combined. Observations on 30th - 31st October 1986 were designated as day 1 while those obtained on 3rd - 4th November 1986 were designated as day 2. Data for other components would be shown as raw data in Appendix 4.2.

## 3.9 STATISTICAL ANALYSIS

All data was analysed using the Statistic Analysis System (SAS) computing package (SAS Institute 1985). All models were linear.

### 3.9.1 YIELDS OF MILK, MILK FAT, MILK PROTEIN, LACTOSE AND CONCENTRATION OF MILK FAT, MILK PROTEIN AND LACTOSE

The above variables were analysed using the repeated measurement analysis of covariance (Finn 1974).

The repeated measurement analysis takes into account the error structure that exists between any two times of measurement for each animal. The null hypothesis that the treatment effects are similar are tested within each time of measurement (See Gill and Hafs 1971). In this experiment repeated measurements were weekly. The analyses were based on the following model:

$$y_{pij} = \mu_p + \alpha_{ip} + \beta_{pxij} + e_{pij}$$

where

$y_{pij}$ = observation on the jth individual measured in the pth week and belonging to the ith treatment

i = 1,2     j = 1,2 ......., 12 for Period I

j = 1,2 ......., 8 for Period II

P = 1, 2, 3     for Period I

p = 1, 2.     for Period II

$\mu_p$ = overall mean together with the effect of the pth week

$\alpha_{ip}$ = the effect of the ith treatment

$x_{ij}$ = the initial observation on the jth individual in the ith treatment

$e_{pij}$ = random residual effects, which are assumed to be identically and independently distributed within the pth week but there being covariance across weeks.

### 3.9.2 LIVEWEIGHT AND BODY CONDITION SCORE CHANGE

Change in LW and CS data were analysed using analysis of variance (Steel and Torrie 1986). The model used to define the above data were:

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

where

$Y_{ij}$ = the observation on the jth individual exposed to the ith treatment i = 1,2     j = 1,2 ....... 12 for period I

j = 1,2 ....... 8 for period II

$\mu$ = the unknown population mean

$\alpha i$ = the effect of the ith treatment

$e_{ij}$ = the random error associated with the jth individual exposed to the ith treatment. It is assumed that $e_{ij}$ is normally distributed with mean 0 and variance $6^2$.

### 3.9.3 FINALLIVEWEIGHTANDFINALBODYCONDITIONSCORE

Final LW and final CS were analysed using the analysis of covariance (Steel and Torrie 1986) as the following model:

$$Y_{ij} = \mu + \alpha_i + ßx_{ij} + e_{ij}$$

where

$Y_{ij}$ = the observation of the jth individual exposed to the ith treatment i = 1,2 j = 1,2 ....... 12 for period I
j = 1,2 ....... 8 for period II

$\mu$ = the unknown population mean

$\alpha_i$ = the effect of the ith treatment

$\beta$ = regression coefficient associated with $x_{ij}$

$x_{ij}$ = pre-experimental performance of the jth cow exposed to the ith treatment

$e_{ij}$ = the random error associated with the jth individual exposed to the ith treatment. It is assumed that $e_{ij}$ is normally distributed with mean 0 and variance $6^2$.

### 3.9.4 HERBAGE MEASUREMENTS - HM, HA, RHM AND DMI

The variables were analysed using paired observations t-test as the data originated from two halves of the same paddock in both periods. The data was analysed using ANOVA (Steel and Torrie 1986) as the following model:

$$Y_{ij} = \mu + \alpha_i + p_j + e_{ij}$$

where

$Y_{ij}$ = the observation of the jth pair of half paddock exposed to the ith treatment i = 1,2 j = 1,2 ....... 8 for period I
j = 1,2 ....... 5 for period II

$\mu$ = the unknown population mean

$\alpha_i$ = the effect of the ith treatment

$p_j$ = a peculiar component to the pair of observations

$e_{ij}$ = the random error associated with the jth individual exposed to the ith treatment. It is assumed that $e_{ij}$ is normally distributed with mean 0 and variance $6^2$

### 3.9.5 GRAZING TIME

Grazing time (GT) data was analysed using ANOVA (Steel and Torrie 1986) as the following model:

$$y_{ij} = \mu + \alpha_i + e_{ij}$$

where

| | | |
|---|---|---|
| $y_{ij}$ | = | the observation of the jth treatment exposed to the ith treatment i = 1,2 j = 1,2 ....... 8 for period II |
| $\mu$ | = | the unknown population mean |
| $\alpha$ | = | the effect of the ith treatment |
| $e_{ij}$ | = | the random error associated with the jth individual exposed to the ith treatment. It is assumed that $e_{ij}$ is normally distributed with mean 0 and variance $6^2$ |

The following symbols will be used throughout this thesis to determine the level of significance of difference between means:

| | | |
|---|---|---|
| *** | Significant difference at the probability ≤ 0.001 | |
| ** | Significant difference at the probability ≤ 0.01 | |
| * | Significant difference at the probability | ≤ 0.05 |
| NS | Not significant difference | > 0.05 |

# Chapter 4

# RESULTS

## 4.1 ANIMAL PRODUCTION RESPONSES

### 4.1.1 MILK PRODUCTION

The results reported in the following tables were adjusted using initial pre-treatment values as covariates (See Appendix 4.1). Initial milk. milk fat, milk protein and lactose yields were used as covariates in the subsequent yields of milk, milk fat, milk protein and lactose respectively. Analyses of concentrations of fat, protein and lactose were also based on their initial concentrations as covariates.

All figures showing yield of milk and milk components and those showing concentrations of milk components include values obtained before and after the experimental periods (3 weeks either way). The data presented in these figures have not been adjusted for covariance.

#### 4.1.1.1 Yields of Milk, Milk Fat, Milk Protein and Lactose

The mean daily yields of each treatment group for the two experimental periods are shown in Table 4.1 together with results of analysis of covariance and in Figures 4.1 to 4.4.

Imposing the treatments of one break or four breaks at common herbage allowance had no significant effect on any component of milk yield or its composition in both periods.

There was no significant effect ($p > 0.05$) with time, neither a significant interaction between time and treatment in any analysis except protein (see below) in the second part of the experiment; therefore the interaction term has been omitted from the presentation in Table 4.1. However relatively high levels of daily milk production were achieved throughout this experiment (21 to 23 kg milk per cow; 0.9 to 1.0 kg milk fat per cow).

(a) Milk Yield

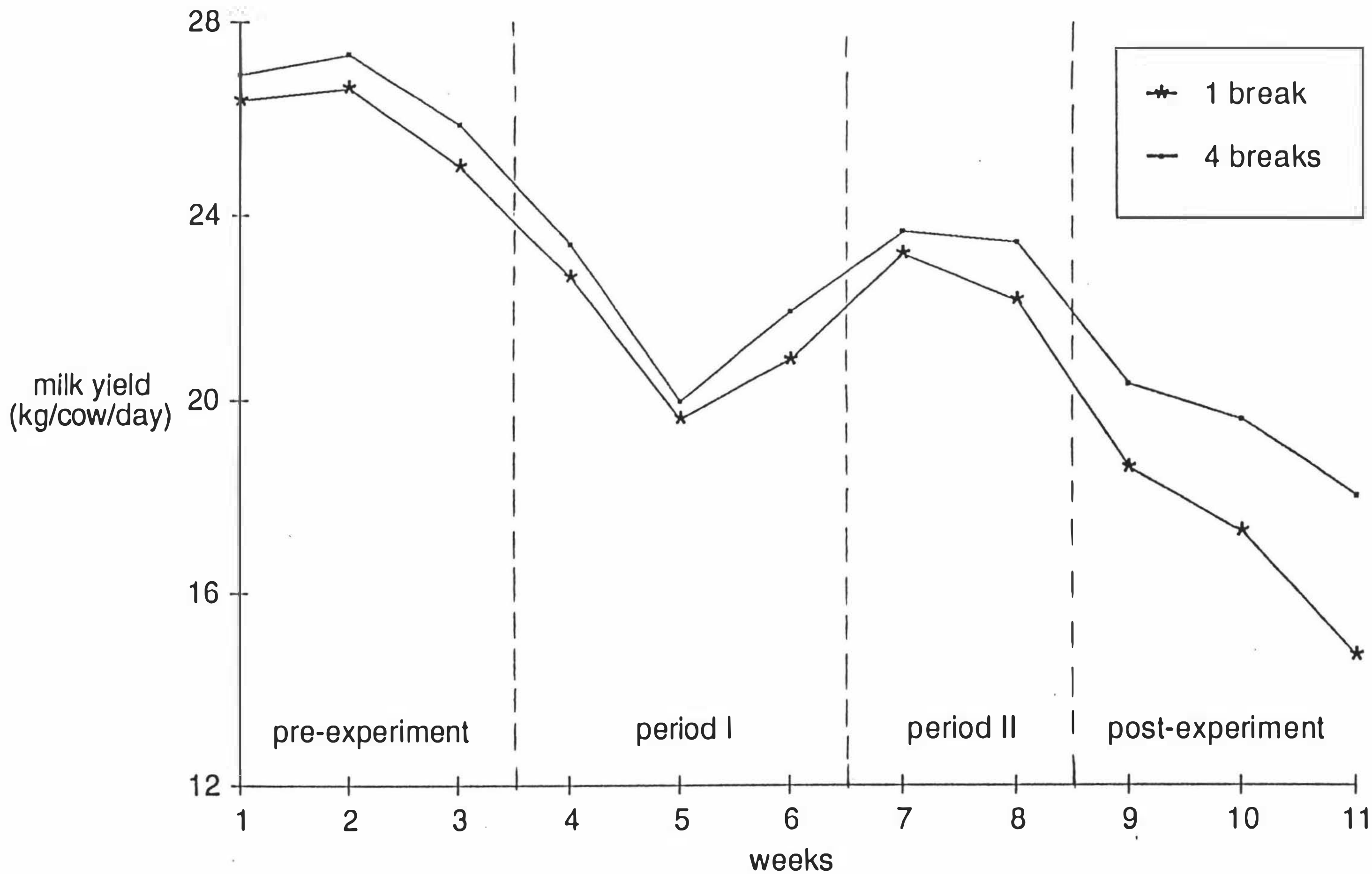
The four break treatment seemed slightly superior in milk yield as depicted in Figure 4.1 and Table 4.1a. Daily responses (Table 4.1a) were 21.3 kg/cow and 21.5 kg/cow for one break and four breaks respectively, during the first experimental period. Period II had higher daily values of 22.8 kg/cow and 23.4 kg/cow for one break and four breaks respectively. The trend reflected mainly a decrease in yield during the second week of period I and subsequent increase in period II, Figure 4.1. During period II, week 2 milk yield was significantly different ($p < 0.05$) between treatments. This had no impact on the overall daily mean.

**Table 4.1: Yields of milk, milk fat, milk protein and lactose for the two treatments in both periods (kg/cow/day) together with results of analysis of covariance**

**(a) Milk Yield**

| Period of Analysis | Treatment 1B | Treatment 4B | SEM | Significance of Effects Treatment | Time | TimexB |
|---|---|---|---|---|---|---|
| Period 1: | | | | | | |
| Week1 | 22.98 | 23.06 | 0.50 | NS | | |
| 2 | 19.86 | 19.72 | 0.54 | NS | | |
| 3 | 21.14 | 21.64 | 0.77 | NS | | |
| x for 3 weeks | 21.33 | 21.47 | | NS | NS | NS |
| Period II: | | | | | | |
| Week 1 | 23.31 | 23.53 | 0.34 | NS | | |
| 2 | 22.29 | 23.31 | 0.33 | * | | |
| x for 2 weeks | 22.80 | 23.42 | | NS | NS | NS |

Figure 4.1 Yields of Milk for the Two Treatments in both Periods



**(b) Milk Fat Yield**

| | 1B | 4B | SEM | Treatment | Time | TimexB |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| Week1 | 0.94 | 0.95 | 0.04 | NS | | |
| 2 | 0.85 | 0.82 | 0.03 | NS | | |
| 3 | 0.88 | 0.90 | 0.03 | NS | | |
| x for 3 weeks | 0.89 | 0.89 | | NS | NS | NS |
| Period II: | | | | | | |
| Week1 | 0.93 | 0.98 | | NS | | |
| 2 | 0.95 | 0.99 | | NS | | |
| x for 2 weeks | 0.94 | 0.99 | | NS | NS | NS |

**(c) Milk Protein Yield**

| | 1B | 4B | SEM | Treatment | Time | TimexB |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| Week 1 | 0.76 | 0.79 | 0.02 | NS | | |
| 2 | 0.65 | 0.65 | 0.02 | NS | | |
| 3 | 0.72 | 0.74 | 0.03 | NS | | |
| x for 3 weeks | 0.71 | 0.73 | | NS | NS | NS |
| Period II: | | | | | | |
| Week 1 | 0.80 | 0.77 | 0.02 | NS | | |
| 2 | 0.75 | 0.80 | 0.01 | ** | | |
| x for 2 weeks | 0.78 | 0.79 | | NS | * | ** |

Figure 4.2 Yields of Milk Fat for the Two Treatments in both Periods

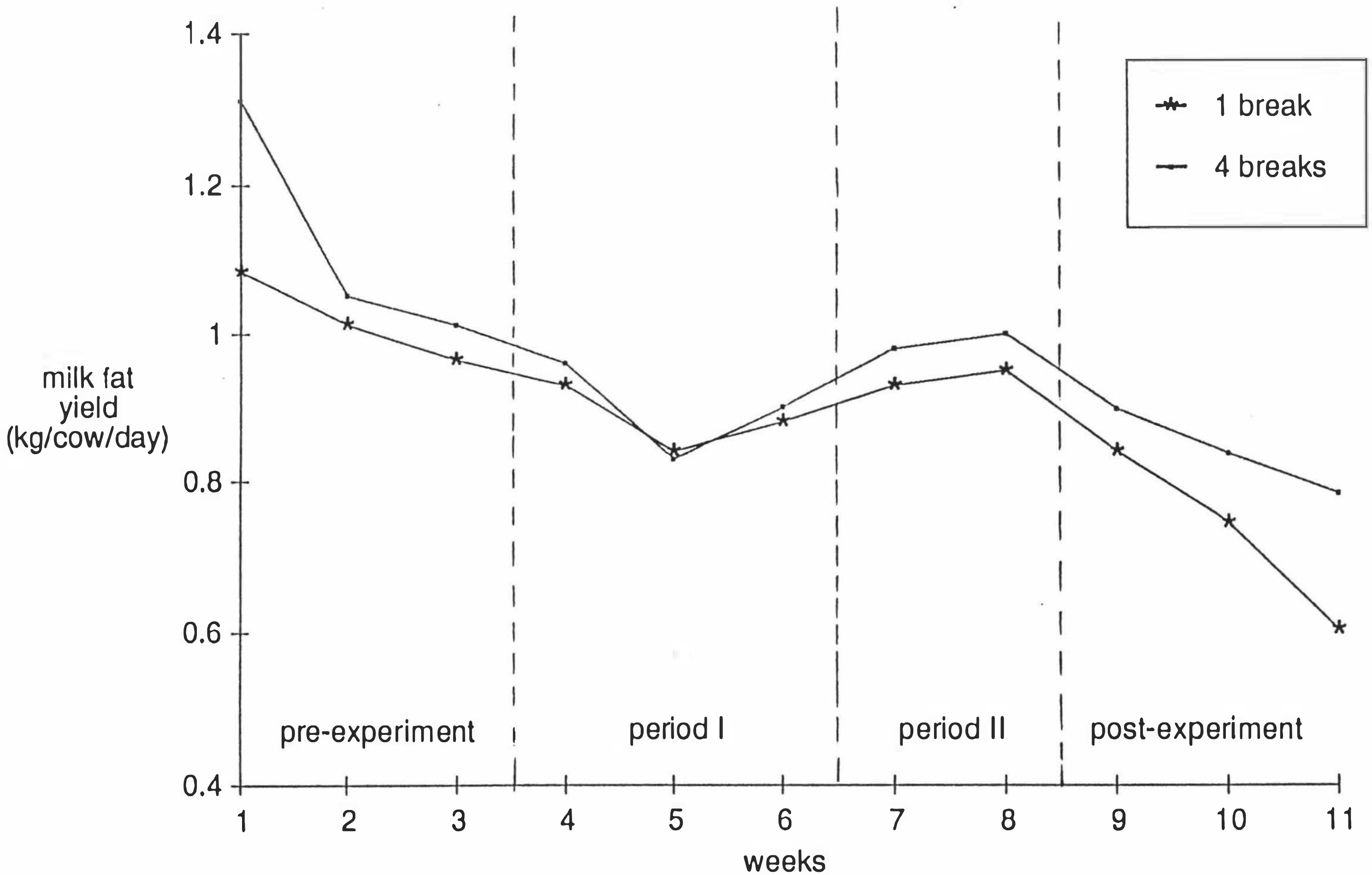
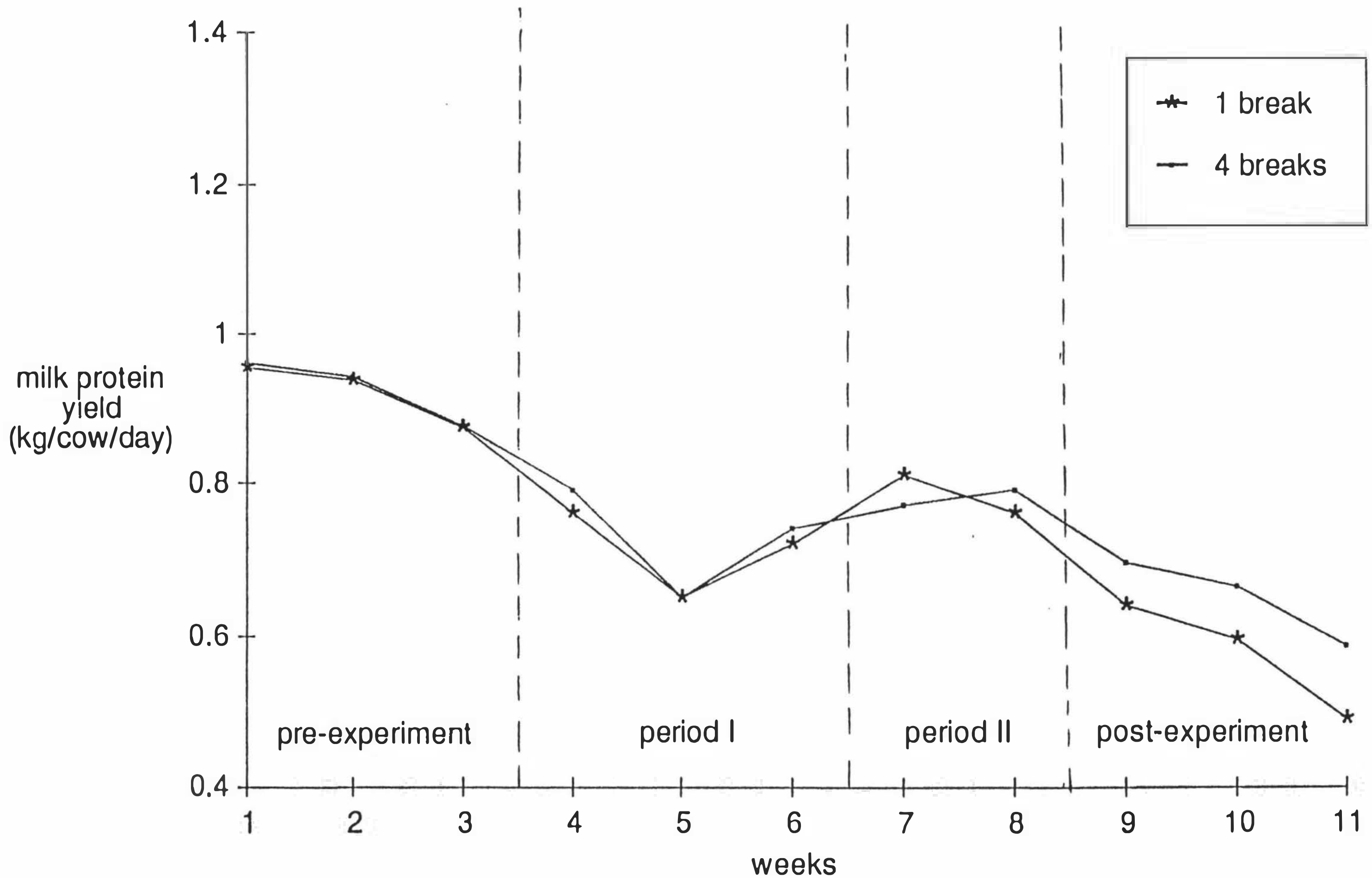


Figure 4.3 Yields of Milk Protein for the Two Treatments in both Periods



**(d) Lactose Yield**

| | 1B | 4B | SEM | Treatment | Time | TimexB |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| Week 1 | 1.16 | 1.17 | 0.02 | NS | | |
| 2 | 0.99 | 1.00 | 0.03 | NS | | |
| 3 | 1.06 | 1.10 | 0.04 | NS | | |
| x for 3 weeks | 1.07 | 1.09 | | NS | NS | NS |
| Period II: | | | | | | |
| Week1 | 1.15 | 1.18 | 0.02 | NS | | |
| 2 | 1.11 | 1.18 | 0.02 | * | | |
| x for 2 weeks | 1.13 | 1.18 | | NS | NS | NS |

Key:

+ Least square means adjusted by covariance

++ *** Significant difference at probability (p) ≤ 0.001

** ≤ 0.01

* ≤ 0.05

NS Not significant > 0.05

These symbols will be used in this and subsequent tables

**(b) Milk Fat Yield**

There were no significant differences between treatments; yields were higher in period I as shown in Table 4.1b and illustrated in Figure 4.2.

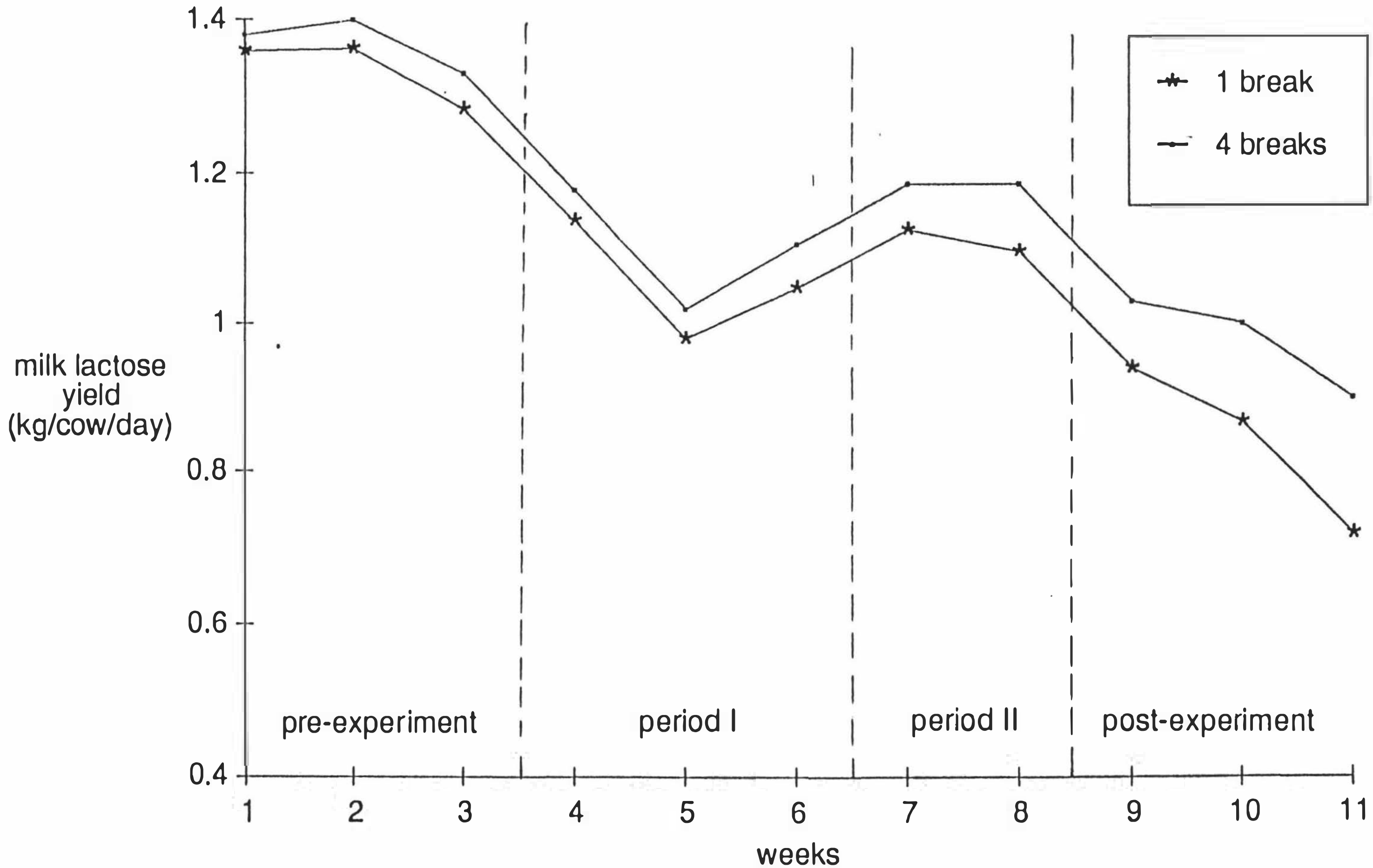
**(c) Milk Protein Yield**

The trend was similar to fat yield with no significant differences between treatments. Higher yields were realised in period II as shown in Table 4.1c and Figure 4.3. Time effect was significant ($p < 0.05$) during period II. During the same period there was high significant interaction between time and treatment ($p < 0.01$).

**(d) Lactose Yield**

There was no significant difference between treatments, yields were higher in period II as shown in Table 4.1d and illustrated in Figure 4.4.

Figure 4.4 Yields of Milk Lactose for the Two Treatments in both Periods



### 4.1.1.2 Concentrations (%) of Milk Fat, Milk Protein and Lactose

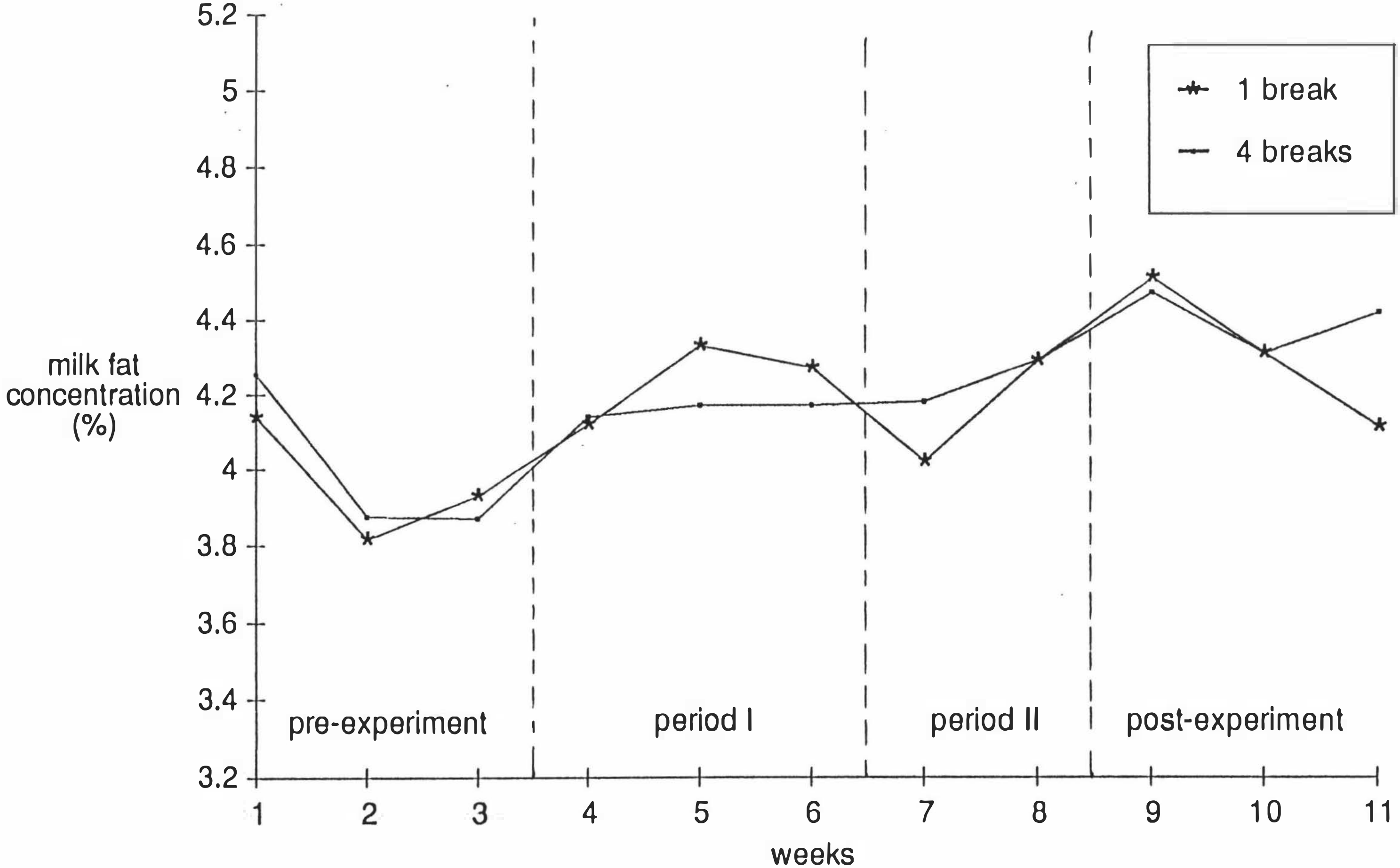
The mean daily concentrations (percentage) of fat, protein and lactose in milk are shown in Table 4.2. Figures 4.5 to 4.7 illustrate the trends of the three constituents: - fat, protein and lactose, respectively, together with the results of analysis of covariance for Table 4.2.

**Table 4.2: Concentrations (%)+ of Milk Fat, Milk Protein and Lactose for the two treatments in both periods, together with results of analysis of covariance.**

**(a) Milk Fat Concentrations**

| Period of Analysis | Treatment | | SEM | Significance of Effects | |
|---|---|---|---|---|---|
| | 1B | 4B | | Treatment | Time |
| Period I: | | | | | |
| Week1 | 4.12 | 4.14 | 0.15 | NS | |
| 2 | 4.33 | 4.17 | 0.13 | NS | |
| 3 | 4.27 | 4.17 | 0.11 | NS | |
| x for 3 weeks | 4.24 | 4.16 | | NS | *** |
| Period II: | | | | | |
| Week1 | 4.02 | 4.18 | 0.09 | NS | |
| 2 | 4.29 | 4.29 | 0.07 | NS | |
| x for 2 weeks | 4.16 | 4.24 | | NS | NS |

Figure 4.5 Concentrations of Milk Fat for the Two Treatments in both Periods



**(b) Milk Protein Concentration**

| Period of Analysis | Treatment | | | Significance of Effects | |
|---|---|---|---|---|---|
| | 1B | 4B | SEM | Treatment | Time |
| Period I: | | | | | |
| Week1 | 3.33 | 3.43 | 0.04 | NS | |
| 2 | 3.30 | 3.30 | 0.04 | NS | |
| 3 | 3.43 | 3.43 | 0.03 | NS | |
| x for 3 weeks | 3.35 | 3.39 | | NS | NS |
| Period II: | | | | | |
| Week 1 | 3.44 | 3.34 | 0.07 | NS | |
| 2 | 3.38 | 3.45 | 0.02 | * | |
| x for 2 weeks | 3.41 | 3.40 | | NS | NS |

**(c) Lactose Concentration**

| Period of Analysis | Treatment | | | Significance of Effects | |
|---|---|---|---|---|---|
| | 1B | 4B | SEM | Treatment | Time |
| Period I: | | | | | |
| Week 1 | 5.05 | 5.06 | 0.04 | NS | |
| 2 | 4.99 | 5.08 | 0.04 | NS | |
| 3 | 5.06 | 5.07 | 0.04 | NS | |
| x for 3 weeks | 5.03 | 5.07 | | NS | NS |
| Period II: | | | | | |
| Week 1 | 4.93 | 5.01 | 0.04 | NS | |
| 2 | 4.98 | 5.08 | 0.02 | ** | |
| x for 2 weeks | 4.96 | 5.05 | | * | NS |

The treatments did not differ significantly in the concentrations of any of the components with the exception of lactose percentage in period II (Table 4.2c).

There was no significant interaction between time and treatment in all analyses; therefore this has been excluded from the presentation in Table 4.2.

Figure 4.6 Concentrations of Milk Protein for the Two Treatments in both Periods

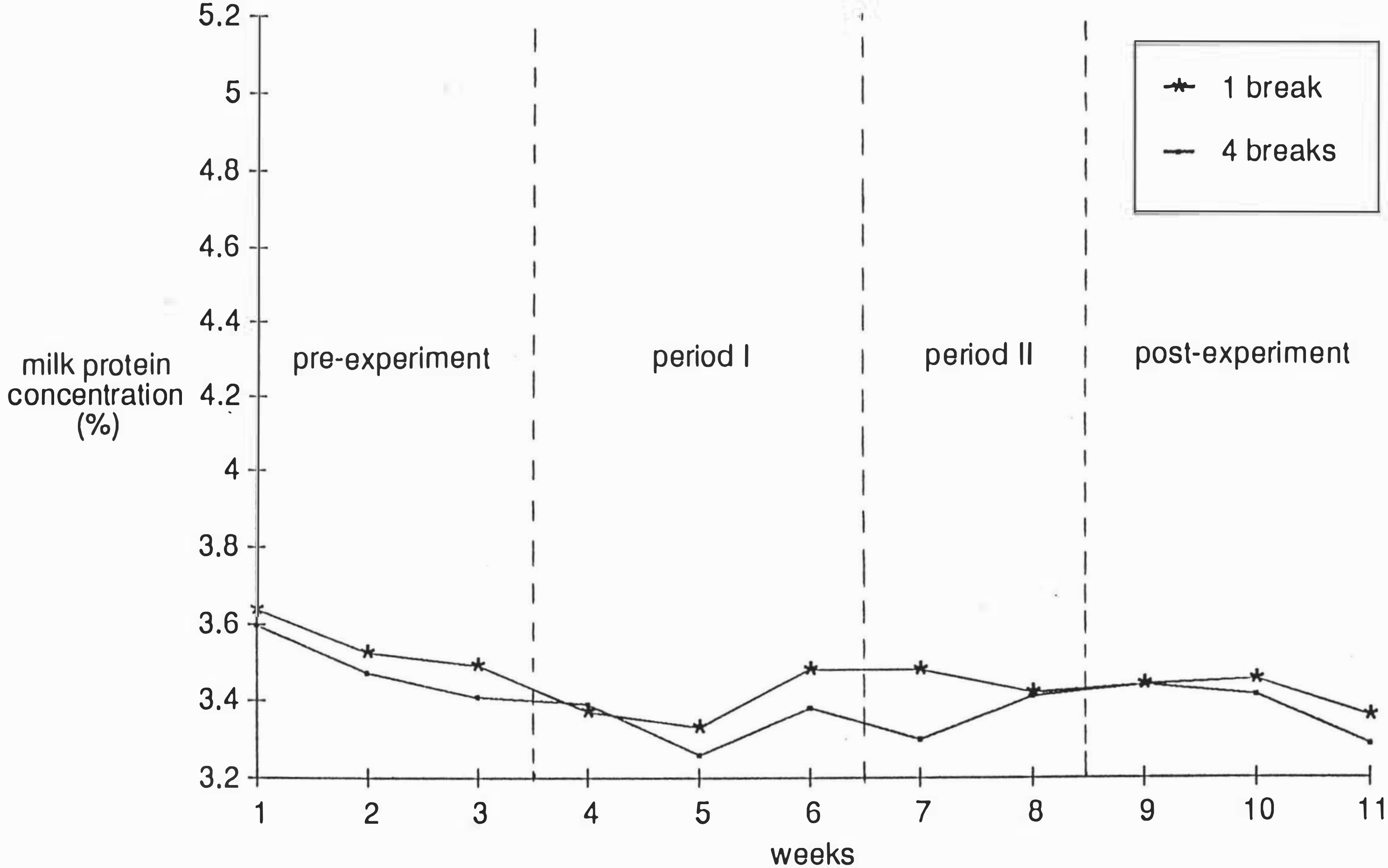
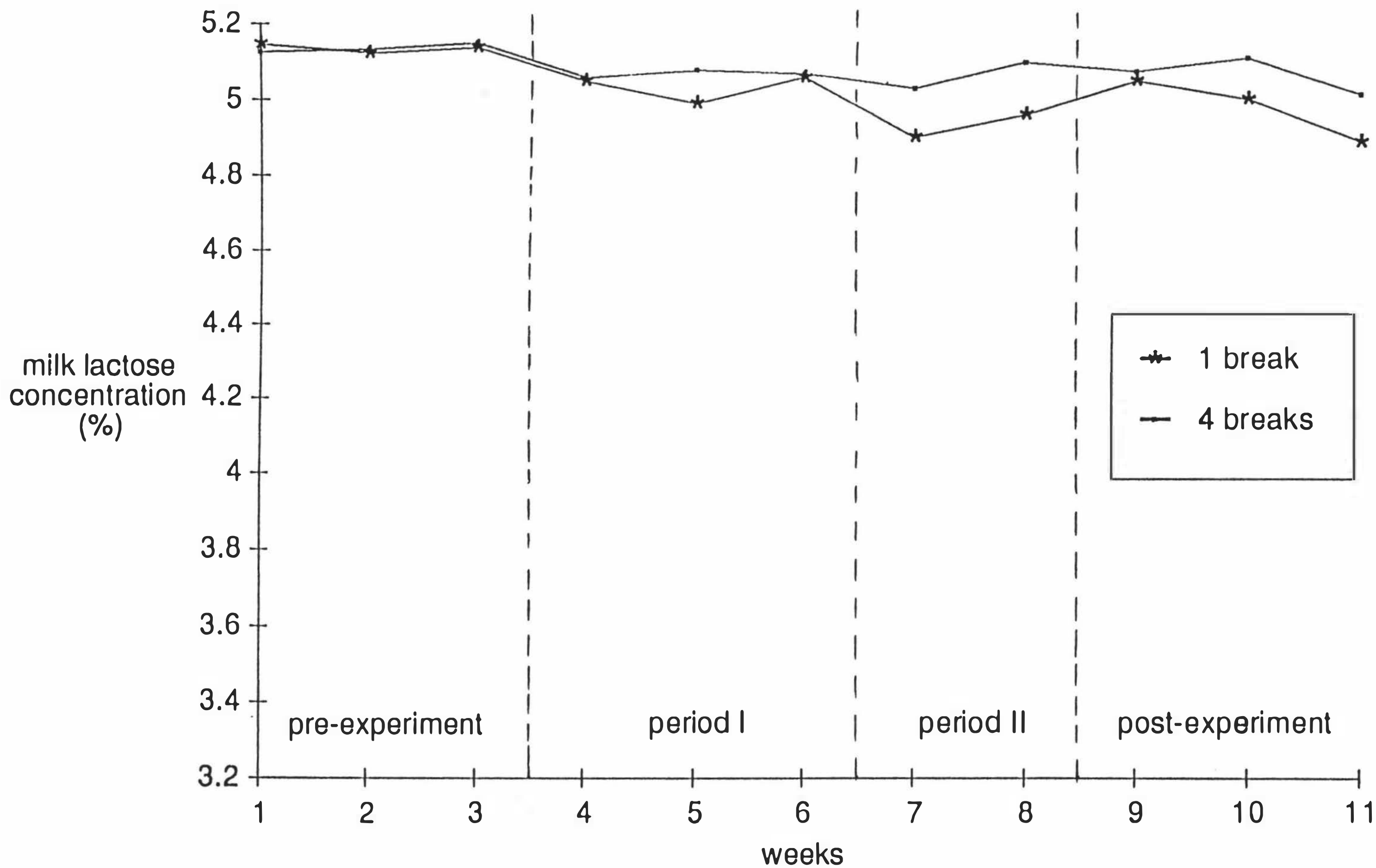


Figure 4.7 Concentrations of Milk Lactose for the Two Treatments in both Periods



**(a) Milk Fat Concentration**

No significant difference was recorded between the two treatments. Effect of time was highly significant ($p< 0.01$) during period I only (Table 4.2a).

**(b) Milk Protein Concentration**

No treatment effect was significant with protein concentration except during period II, week 2 ($p< 0.05$). There was no significant effect of time either (Table 4.2b).

**(c) Lactose Concentration**

There was a significant difference between the treatment groups ($p< 0.05$) during period II. The daily means for week 2 which were significantly different ($p<0.01$) were 4.98% and 5.08% for the 1B and for the 4B respectively. The combined daily means for that period (II) were 4.96% and 5.05% for the 1B and for the 4B respectively (Table 4.2c) they were significantly ($p< 0.05$) different.

Time effect and interaction between time and treatment were non-significant ($p>0.05$).

#### 4.1.1.3 Yields of Milk, Milk Fat, Milk Protein and Lactose for Evening (PM) and Morning (AM) Milkings

The mean daily yields of each treatment group for evening (PM) and morning (AM) milking for the two experimental periods are shown in Table 4.3 to 4.6 together with results of analysis of covariance. The effect of time and interaction between time and treatment were not significant in any analysis for both periods; therefore these have been eliminated from the presentation.

Evening yields were clearly lower than morning yields for both treatment groups. This difference may be explained largely by the unequal milking interval i.e. 9 hours prior to PM and 15 hours prior to AM milkings.

**Table 4.3: PM and AM yields+ of milk for the two treatments in both periods (kg/cow/day) together with results of analysis of covariance.**

| Period of Analysis | Treatment 1B | Treatment 4B | 4B Yield % Relative to 1B | SEM | Significance of Effects: Treatment | Significance of Effects: Time |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| PM Week 1 | 9.75 | 9.35 | | 0.49 | NS | |
| 2 | 7.56 | 7.28 | | 0.30 | NS | |
| 3 | 8.43 | 8.55 | | 0.46 | NS | |
| AM 1 | 13.09 | 13.72 | | 0.58 | NS | |
| 2 | 12.32 | 12.49 | | 0.38 | NS | |
| 3 | 12.68 | 13.17 | | 0.45 | NS | |
| x for 3 weeks | | | | | | |
| PM | 8.58 | 8.39 | 98 | | NS | NS |
| AM | 12.70 | 13.13 | 103 | | NS | NS |
| % Increase | 48 | 57 | | | | |
| Period II: | | | | | | |
| PM Week 1 | 9.19 | 8.79 | | 0.39 | NS | |
| 2 | 8.93 | 9.07 | | 0.32 | NS | |
| AM 1 | 14.41 | 14.67 | | 0.50 | NS | |
| 2 | 13.20 | 14.21 | | 0.59 | NS | |
| x for 2 weeks | | | | | | |
| PM | 9.06 | 8.93 | 99 | | NS | NS |
| AM | 13.81 | 14.44 | 105 | | NS | NS |
| % Increase | 52 | 62 | | | | |

**(a) <u>Milk Yield and Lactose</u>**

In both periods the 4B group produced more milk (Table 4.3) and lactose (Table 4.6) at the AM milking, but less at the PM milking than the 1B group. However none of these differences was significant. AM yield for both milk and lactose was 60% greater than the PM yield for the 4B group but 50% greater than the PM yield for the 1B group during the experimental period. For lactose alone time effect was significant ($p< 0.05$) for AM milking during period I and not during period II (Table 4.6).

**(b) Milk Fat Yield**

There was no consistent difference between the treatments with respect to the AM yield relative to the PM yield (Table 4.4). AM yield was about 8% larger than PM yield for the 1B group but 6% larger than the PM yield for the 4B group on the average. All analyses were non significant ($p > 0.05$) except during week 2, period I for the AM milking.

**(c) Milk Protein Yield**

There was no consistent difference again between the treatments with respect to the AM yield relative to the PM yield. On the average AM yield was about 58% greater than PM yield.

**Table 4.4: PM and AM yields⁺ of milk fat for the two treatments in both periods (kg/cow/day) together with results of analysis of covariance.**

| Period of Analysis | | Treatment 1B | Treatment 4B | 4B yield(%) relative to 1B | SEM | Significance of Effects: Treatment | Time |
|---|---|---|---|---|---|---|---|
| Period I: | | | | | | | |
| PM Week | 1 | 0.475 | 0.473 | | 0.03 | NS | |
| | 2 | 0.372 | 0.380 | | 0.02 | NS | |
| | 3 | 0.419 | 0.439 | | 0.02 | NS | |
| AM | 1 | 0.469 | 0.473 | | 0.03 | NS | |
| | 2 | 0.488 | 0.430 | | 0.02 | * | |
| | 3 | 0.474 | 0.447 | | 0.02 | NS | |
| x for 3 weeks | | | | | | | |
| PM | | 0.422 | 0.431 | 102 | | NS | NS |
| AM | | 0.477 | 0.450 | 94 | | NS | NS |
| % Increase | | 13 | 4 | | | | |
| Period II: | | | | | | | |
| PM Week | 1 | 0.466 | 0.463 | | 0.02 | NS | |
| | 2 | 0.465 | 0.473 | | 0.02 | NS | |
| AM | 1 | 0.468 | 0.507 | | 0.01 | NS | |
| | 2 | 0.486 | 0.505 | | 0.03 | NS | |
| x for 2 weeks | | | | | | | |
| PM | | 0.466 | 0.468 | 100 | | NS | NS |
| AM | | 0.477 | 0.506 | 106 | | NS | NS |
| % Increase | | 2 | 8 | | | | |

**Table 4.5: PM and AM yields+ of milk protein for the two treatments in both periods (kg/cow/day) together with results of analysis of covariance.**

| Period of Analysis | Treatment | | 4B yield(%) relative to | | Significance of Effects | |
|---|---|---|---|---|---|---|
| | 1B | 4B | 1B | SEM | Treatment | Time |
| Period I: | | | | | | |
| PM Week 1 | 0.310 | 0.317 | | 0.02 | NS | |
| 2 | 0.241 | 0.241 | | 0.01 | NS | |
| 3 | 0.280 | 0.294 | | 0.01 | NS | |
| AM 1 | 0.449 | 0.467 | | 0.02 | NS | |
| 2 | 0.413 | 0.400 | | 0.01 | NS | |
| 3 | 0.445 | 0.441 | | 0.02 | NS | |
| x for 3 weeks | | | | | | |
| PM | 0.277 | 0.284 | 103 | | NS | NS |
| AM | 0.436 | 0.436 | 100 | | NS | NS |
| % Increase | 58 | 54 | | | | |
| Period II: | | | | | | |
| PM Week 1 | 0.303 | 0.298 | | 0.01 | NS | |
| 2 | 0.309 | 0.305 | | 0.02 | NS | |
| AM 1 | 0.491 | 0.501 | | 0.01 | NS | |
| 2 | 0.458 | 0.481 | | 0.01 | NS | |
| x for 2 weeks | | | | | | |
| PM | 0.306 | 0.302 | 99 | | NS | NS |
| AM | 0.475 | 0.491 | 103 | | | NS |
| % Increase | 55 | 63 | | | | |

**Table 4.6: PM and AM yields+ of Lactose for the two treatments in both periods (kg/cow/day) together with results of analysis of covariance.**

| Period of Analysis | | Treatment 1B | 4B | 4B yield(%) relative to 1B | SEM | Significance of Effects Treatment | Time |
|---|---|---|---|---|---|---|---|
| Period I: | | | | | | | |
| PM Weeks | 1 | 0.488 | 0.471 | | 0.02 | NS | |
| | 2 | 0.380 | 0.366 | | 0.02 | NS | |
| | 3 | 0.425 | 0.431 | | 0.02 | NS | |
| AM | 1 | 0.671 | 0.694 | | 0.03 | NS | |
| | 2 | 0.615 | 0.625 | | 0.02 | NS | |
| | 3 | 0.631 | 0.668 | | 0.02 | NS | |
| x for 3 weeks | | | | | | | |
| PM | | 0.431 | 0.423 | 98 | | NS | NS |
| AM | | 0.639 | 0.662 | 104 | | NS | * |
| % Increase | | 48 | 57 | | | | |
| Period II: | | | | | | | |
| PM Week | 1 | 0.464 | 0.437 | | 0.02 | NS | |
| | 2 | 0.452 | 0.453 | | 0.02 | NS | |
| AM | 1 | 0.727 | 0.728 | | 0.01 | NS | |
| | 2 | 0.667 | 0.714 | | 0.02 | NS | |
| x for 2 weeks | | | | | | | |
| PM | | 0.458 | 0.445 | 97 | | NS | NS |
| AM | | 0.697 | 0.721 | 103 | | NS | NS |
| % Increase | | 53 | 62 | | | | |

#### 4.1.1.4 Concentrations of Milk Fat, Milk Protein and Lactose for Evening (PM) and Morning (AM) Milking

The mean daily PM and AM concentrations (percentages in milk) of fat, protein and lactose in milk are shown in Tables 4.7, 4.8 and 4.9 respectively together with the results of analysis of covariance.

The interaction between time and treatment was not significant in any analysis in both periods; therefore it has been omitted from the presentation in Tables 4.7 - 4.9. The effect of time was significant only for milk fat for AM milking ($p< 0.01$) during period I.

**Table 4.7: PM and AM concentrations(%) of milk fat⁺ for the two treatments in both periods together with results of analysis of covariance.**

| Period of Analysis | Treatment 1B | Treatment 4B | 4B yield(%) relative to 1B | SEM | Significance of Effects: Treatment | Significance of Effects: Time |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| PM Week 1 | 4.87 | 5.02 | | 0.12 | NS | |
| 2 | 4.81 | 5.24 | | 0.15 | * | |
| 3 | 4.99 | 5.20 | | 0.11 | NS | |
| AM 1 | 3.55 | 3.61 | | 0.14 | NS | |
| 2 | 3.96 | 3.50 | | 0.14 | * | |
| 3 | 3.78 | 3.45 | | 0.11 | * | |
| x for 3 weeks | | | | | | |
| PM | 4.89 | 5.15 | 105 | | * | NS |
| AM | 3.76 | 3.52 | 94 | | NS | ** |
| Period II: | | | | | | |
| PM Week 1 | 5.17 | 5.23 | | 0.11 | NS | |
| 2 | 5.22 | 5.22 | | 0.17 | NS | |
| AM 1 | 3.23 | 3.66 | | 0.16 | NS | |
| 2 | 3.54 | 3.68 | | 0.84 | NS | |
| x for 2 weeks | | | | | | |
| PM | 5.20 | 5.23 | 101 | | NS | NS |
| AM | 3.39 | 3.65 | 108 | | * | NS |

**(a) Milk Fat Concentrations**

Fat content was higher for the PM than the AM milkings in both treatments and in both periods. There were no consistent differences between treatments in both periods, although values for the 4B were significantly larger than for the 1B in most cases including AM milkings. The net effect was a significant difference ($p < 0.05$) for the PM milking in period I. A similar level of significance was noted for the AM milking during period II.

**Table 4.8: PM and AM concentrations (%) of milk protein+ for the two treatments in both periods, together with results of analysis of covariance.**

| Period of Analysis | Treatment 1B | Treatment 4B | 4B yield(%) relative to 1B | SEM | Significance of Effects: Treatment | Significance of Effects: Time |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| PM Week 1 | 3.26 | 3.41 | | 0.04 | ** | |
| 2 | 3.23 | 3.31 | | 0.03 | NS | |
| 3 | 3.36 | 3.46 | | 0.04 | NS | |
| AM 1 | 3.46 | 3.42 | | 0.05 | NS | |
| 2 | 3.38 | 3.22 | | 0.04 | ** | |
| 3 | 3.52 | 3.35 | | 0.04 | ** | |
| x for 3 weeks | | | | | | |
| PM | 3.28 | 3.39 | 103 | | ** | NS |
| AM | 3.45 | 3.33 | 97 | | ** | NS |
| Period II: | | | | | | |
| PM Week 1 | 3.34 | 3.37 | | 0.03 | NS | |
| 2 | 3.37 | 3.34 | | 0.05 | NS | |
| AM 1 | 3.44 | 3.51 | | 0.06 | NS | |
| 2 | 3.41 | 3.47 | | 0.03 | NS | |
| x for 2 weeks | | | | | | |
| PM | 3.36 | 3.36 | 100 | | NS | NS |
| AM | 3.43 | 3.49 | 102 | | NS | NS |

**(b) Milk Protein Concentration**

There was no consistent differences between PM and AM milkings. Treatment effects were recorded during period I but not during period II. There were irregular differences between treatments (Table 4.8). Treatment effects were significant for AM ($p < 0.01$) and PM ($p < 0.01$) milkings during period I.

**Table 4.9: PM and AM concentrations (%) of Lactose+ for the two treatments in both periods together with results of analysis of covariance.**

| Period of Analysis | Treatment 1B | 4B | 4B yield(%) relative to 1B | SEM | Significance of Effects Treatment | Time |
|---|---|---|---|---|---|---|
| Period I: | | | | | | |
| PM Week 1 | 5.05 | 5.04 | | 0.03 | NS | |
| 2 | 5.03 | 5.03 | | 0.04 | NS | |
| 3 | 5.08 | 5.03 | | 0.04 | NS | |
| AM 1 | 5.11 | 5.06 | | 0.04 | NS | |
| 2 | 5.00 | 5.10 | | 0.03 | * | |
| 3 | 5.08 | 5.06 | | 0.05 | NS | |
| x for 3 weeks | | | | | | |
| PM | 5.05 | 5.03 | 100 | | NS | NS |
| AM | 5.06 | 5.07 | 100 | | NS | NS |
| Period II: | | | | | | |
| PM Week 1 | 4.97 | 4.98 | | 0.03 | NS | |
| 2 | 4.98 | 5.03 | | 0.02 | NS | |
| AM 1 | 5.00 | 5.04 | | 0.03 | NS | |
| 2 | 5.00 | 5.08 | | 0.02 | NS | |
| x for 2 weeks | | | | | | |
| PM | 4.98 | 5.01 | 101 | | NS | NS |
| AM | 5.00 | 5.06 | 101 | | NS | NS |

(c) <u>Lactose Concentration</u>

Lactose content was slightly higher in AM than in PM milking in both periods. Between the treatment groups the differences were very small and inconsistent. The only significance was recorded during period I week 2 ($p < 0.05$) for AM milking.

### 4.1.1.5 Interactions Between Time of Day Effect and Treatment Effect on Yield

The differences in yield (kg/cow/day) of milk, milk fat, milk protein and lactose between evening (PM) and morning (AM) production (AM yield minus PM yield) are shown in Table 4.10.

No significant effect was recorded for both time and interaction between time and treatment in any of the analyses. Therefore these have been omitted from the presentation in Table 4.10.

**Table 4.10 Differences in yields [+§] (kg/cow/day) of milk, milkfat, milk protein and lactose between morning (AM) and evening (PM) production in both periods together with results of analysis of covariance.**

(a) Milk Yields

| Period of Analysis | Treatment | | | Significance of effects |
|---|---|---|---|---|
| | 1 B | 4 B | SEM | Treatment |
| Period I | | | | |
| Week 1 | 3.35 | 4.37 | 0.86 | NS |
| 2 | 4.76 | 5.24 | 0.49 | NS |
| 3 | 4.28 | 4.60 | 0.35 | NS |
| x for 3 weeks | 4.13 | 4.74 | | NS |
| Period II | | | | |
| Week 1 | 5.22 | 5.88 | 0.56 | NS |
| 2 | 4.29 | 5.15 | 0.64 | NS |
| x for 2 weeks | 4.76 | 5.52 | | NS |

**(a) Milk Yield and Lactose Yield**

In both periods the difference (AM yield minus PM yield) was larger for the 4B group than for the 1B group. However the differences between groups was not significant (Tables 4.10a and 4.10d).

**(b) Milk fat yield**

| Period of Analysis | Treatment | | | Significance of Effects |
|---|---|---|---|---|
| | 1 Break | 4 Breaks | SEM | |
| Period I | | | | |
| Week1 | 0.0058 | 0.0002 | 0.05 | NS |
| 2 | 0.1156 | 0.0496 | 0.03 | ** |
| 3 | 0.0542 | 0.0075 | 0.02 | ** |
| x of 3 weeks | 0.0585 | 0.0191 | | ** |
| Period II | | | | |
| Week1 | 0.0025 | 0.0429 | 0.03 | NS |
| 2 | 0.0206 | 0.0320 | 0.04 | NS |
| x for 2 weeks | 0.0116 | 0.0375 | | NS |

**(b) Milk Fat Yield**

Significant differences were recorded in several cases during period I as shown in Table 4.10b. The effect of treatment was not significant during period II. In all cases the difference in fat yield (AM yield minus PM yield) was larger for the 1B than the 4B.

**(c) Milk Protein Yield**

| Period of Analysis | Treatment | | | Significance of Effects |
|---|---|---|---|---|
| | 1 Break | 4 Breaks | SEM | Treatment |
| Period I: | | | | |
| Week1 | 0.139 | 0.148 | 0.03 | NS |
| 2 | 0.172 | 0.159 | 0.02 | NS |
| 3 | 0.164 | 0.164 | 0.01 | NS |
| x for 3 weeks | 0.158 | 0.151 | | NS |
| Period II: | | | | |
| Week1 | 0.187 | 0.202 | 0.02 | NS |
| 2 | 0.148 | 0.176 | 0.03 | NS |
| x for 2 weeks | 0.168 | 0.189 | | NS |

**(c) Milk Protein Yield**

There were no consistent, non-significant differences between the treatments with respect to the differences between AM and PM yields (Table 4.10c).

**(d) Lactose Yield**

| Period of Analysis | Treatment | | | Significance of Effects |
|---|---|---|---|---|
| | 1 Break | 4 Breaks | SEM | Treatment |
| Period I: | | | | |
| Week1 | 0.183 | 0.223 | 0.05 | NS |
| 2 | 0.235 | 0.259 | 0.02 | NS |
| 3 | 0.206 | 0.238 | 0.02 | NS |
| x for 3 weeks | 0.208 | 0.240 | | NS |
| Period II: | | | | |
| Week1 | 0.266 | 0.294 | 0.03 | NS |
| 2 | 0.219 | 0.264 | 0.03 | NS |
| x for 2 weeks | 0.242 | 0.279 | | NS |

#### 4.1.1.6 Interaction Between Time of Day Effect and Treatment Effect on Concentration of Milk Components

The differences in concentration (%) of milk fat, milk protein and lactose between morning and evening production are shown in Table 4.11.

Similar to the yields (section 4.1.1.5) there was no significant effect for both time and interaction between time and treatment in any of the analyses. Therefore they have been omitted from the presentations in Tables 4.11a - c. Daily (AM% - PM%) means for these differences are shown in the Tables.

**Table 4.11: Differences in concentrations (%)+ of milk fat, milk protein and lactose between morning (AM) and evening (PM) production in both periods together with results of analysis of covariance.**

**(a) Milk Fat Concentration (AM - PM)**

| Period of Analysis | Treatment 1 Break | 4 Breaks | SEM | Significance of Effects Treatment |
|---|---|---|---|---|
| Period I: | | | | |
| Week 1 | -1.30 | -1.44 | 0.15 | NS |
| 2 | -0.86 | -1.72 | 0.18 | ** |
| 3 | -1.20 | -1.76 | 0.15 | ** |
| x for 3 weeks | -1.12 | -1.64 | | *** |
| Period II: | | | | |
| Week1 | -1.89 | -1.62 | 0.17 | NS |
| 2 | -1.75 | -1.47 | 0.21 | NS |
| x for 2 weeks | -1.82 | -1.55 | | NS |

**(b) Milk Protein Concentration (AM - PM)**

| Period of Analysis | Treatment 1 Break | 4 Breaks | SEM | Significance of Effects Treatment |
|---|---|---|---|---|
| Period I: | | | | |
| Week 1 | 0.201 | -0.009 | 0.03 | *** |
| 2 | 0.154 | -0.091 | 0.04 | *** |
| 3 | 0.166 | -0.104 | 0.04 | *** |
| x for 3 weeks | 0.174 | -0.068 | | *** |
| Period II: | | | | |
| Week 1 | 0.092 | 0.141 | 0.06 | NS |
| 2 | 0.045 | 0.123 | 0.03 | NS |
| x for 2 weeks | 0.069 | 0.132 | | NS |

High values in concentration differences between AM and PM productions were noted with milk fat concentration (Table 4.11a). During period I there was a strong significant difference ($p < 0.001$) between treatments but not during period II.

Although protein had relatively small values the significance level was similar to fat concentration i.e. a strong significance for treatment effect ($p < 0.001$) for period I but non for period II (Table 4.11b). Lactose was insensitive to all treatments for both periods (Table 4.11c).

**(c) Lactose Concentration (AM - PM)**

| Period of Analysis | Treatment | | | Significance of Effects |
|---|---|---|---|---|
| | 1 Break | 4 Breaks | SEM | Treatment |
| Period I: | | | | |
| Week 1 | 0.0661 | 0.0247 | 0.04 | NS |
| 2 | 0.0386 | 0.0728 | 0.02 | *** |
| 3 | 0.0024 | 0.0196 | 0.05 | NS |
| x for 3 weeks | 0.0357 | 0.0390 | | NS |
| Period II: | | | | |
| Week 1 | 0.024 | 0.056 | 0.02 | NS |
| 2 | 0.025 | 0.046 | 0.02 | NS |
| x for 2 weeks | 0.024 | 0.051 | | NS |

### 4.1.2 LIVEWEIGHT AND BODY CONDITION SCORE

The mean daily values for the initial liveweight, the final liveweight adjusted for initial weight, liveweight change, the initial condition score, the final condition score adjusted for initial score and change in condition score are given in Table 4.12.

Changes in unfasted liveweight and unfasted condition score over the 35 day experimental period did not differ significantly between treatments (Table 4.12) despite the fact that 1B gained 0.39kg/day while 4B lost 0.08kg/day during period I. During period II 1B gained 0.72 kg/day whereas 4B gained 0.42 kg/day. There was little loss in condition score (0.06 units per month for the 1B and 0.02 units per month for 4B) during period I. During period II the control group (1B) lost 0.02 units per month while the experimental group (4B) gained 0.38 units per month.

**Table 4.12: Unfasted liveweight, liveweight change, body condition score and condition score change+ for the two treatments for both periods.**

**(a) Period I**

| | Treatment 1 Break | 4 Breaks | SEM | Signific. Level |
|---|---|---|---|---|
| Initial Liveweight (kg) | 462 | 460 | 5 | NS |
| Final Liveweight (kg) | 470 | 458 | 6 | NS |
| Liveweight change (kg) Per day | +0.39 | -0.08 | 54 | NS |
| Initial Condition Score (units) | 4.67 | 4.57 | 0.07 | NS |
| Final Condition Score (units) | 4.63 | 4.54 | 0.06 | NS |
| C.S. change (units/month) | -0.06 | -0.02 | 0.06 | NS |

**(b) Period II**

| | Treatment 1 Break | 4 Breaks | SEM | Signific. Level |
|---|---|---|---|---|
| Initial Liveweight (kg) | 498 | 487 | 5 | NS |
| Final Liveweight (kg) | 508 | 492 | 5 | NS |
| Liveweight change (kg) per day | +0.72 | +0.42 | 35 | NS |
| Initial Condition Score (units) | 4.79 | 4.76 | 0.05 | NS |
| Final Condition Score (units) | 4.77 | 4.94 | 0.06 | NS |
| C.S. Change (units/ month) | -0.02 | +0.38 | 0.03 | NS |

### 4.1.3 GRAZING BEHAVIOUR

Only the data for daylight grazing time have been subjected to statistical analyses. Night-time grazing time was not analysed statistically because it was derived from treatment group averages. The same applies to total time (day + night) for the individual days as it included the night-time hours of grazing.

Values for other grazing components will be shown as raw data in Appendix 4.2 and cover only daylight hours for the separate days i.e. 30th - 31st October (day 1) and 3rd - 4th November (day 2) 1986.

#### 4.1.3.1 Grazing Time

Grazing time (GT) for day and night (unanalysed) hours is shown in Table 4.13 in minutes. The same values have been presented in patterns as shown in Figures 4.8 and 4.9.

Daylight (day time) grazing time was not significantly different between treatment groups for the separate days. The night-time data though unanalysed indicate (not statistically) high significant difference between the treatment groups with the 1 Break grazing at longer hours than the 4 Break in both days (Table 4.13). The same effect is observed when combining the night and day values for both days.

There was no significant difference between the treatments in total GT during daylight hours for the two days combined giving 464 minutes or 7.75 hours of grazing for the 1 Break and 473 minutes or 7.88 hours of grazing for the 4 Break.

The diurnal patterns of grazing time are shown in Figures 4.8 and 4.9. The 1 Break group grazed steadily throughout the night except between 03.00 and 04.00 for each day, because feed was available, whereas the 4 Break group stopped grazing for about 3 hours and 4 hours on day 1 and day 2 respectively after the first break had been offered. This happened because this break was quickly eaten up within this short period of time (Figures 4.8 and 4.9).

The four break group began grazing steadily again at 04.00 when the second break was given. The 1 Break group also started grazing about this time but less vigorously until morning milking. Both groups grazed vigorously after the morning milking but the activity waned until in the afternoon when the fourth (final) break was received.

**Table 4.13 Grazing time (minutes)+ for a 24 hour period on 30th-31st October (Day 1) and 3rd - 4th November (Day 2) 1986 for the feeding frequency treatment.**

| | | Treatment | | | |
|---|---|---|---|---|---|
| | | 1 Break | 4 Breaks | SEM | Signific. Level |
| Daytime | Day 1 | 483.8 | 468.9 | 16.09 | NS |
| | Day 2 | 444.4 | 476.3 | 16.49 | NS |
| Night | Day 1 | 180.0 | 79.0 | | unanalysed |
| | Day 2 | 144.0 | 49.0 | | unanalysed |
| Total | Day 1 | 663.8 | 547.8 | | unanalysed |
| | Day 2 | 588.4 | 525.3 | | unanalysed |
| Combined (Day 1 + Day 2) | | | | | |
| Daytime (average) | | 464.0 | 472.5 | 13.75 | NS |

\+ Least Square Means

In effect a circadian pattern was developed by the one break group with the major grazing periods beginning after evening milking, near dawn, mid-morning (after the morning milking) and late afternoon (Arnold 1985). This was not possible with the experimental group as feed was not available all the time within the 24 hour period. It can be noticed that although the four break group had their second break at 0400 hours the intensity of grazing did not reach the maximum rate of 60 minutes per hour (Figures 4.8 and 4.9). A similar situation was recorded as the fourth break was received in both days.

Figure 4.8 Proportion of each hour of the day spent grazing on 30th-31st October 1986

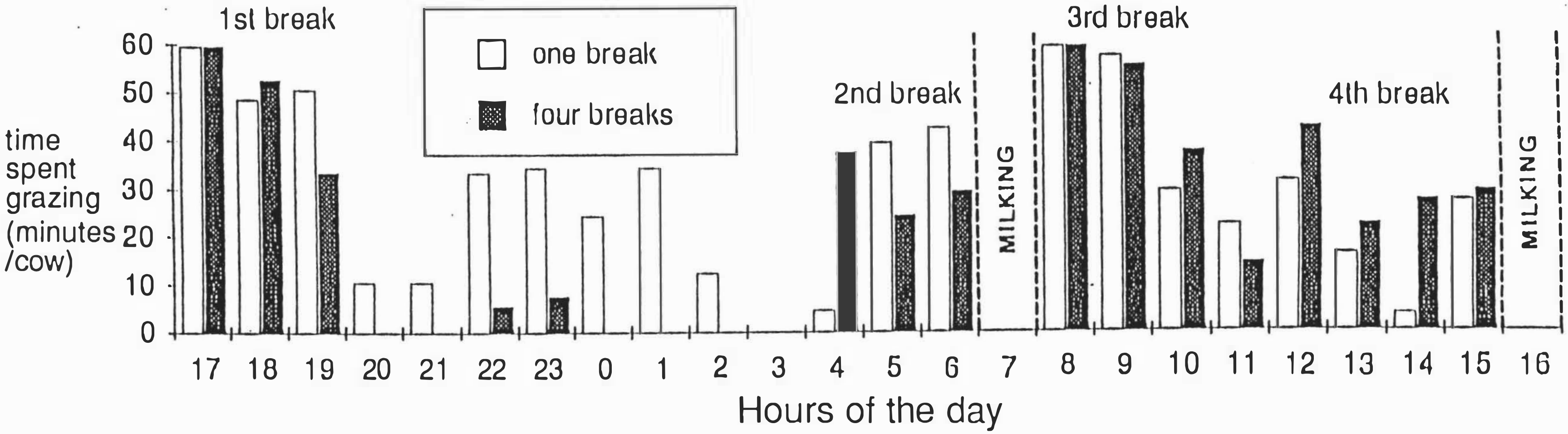
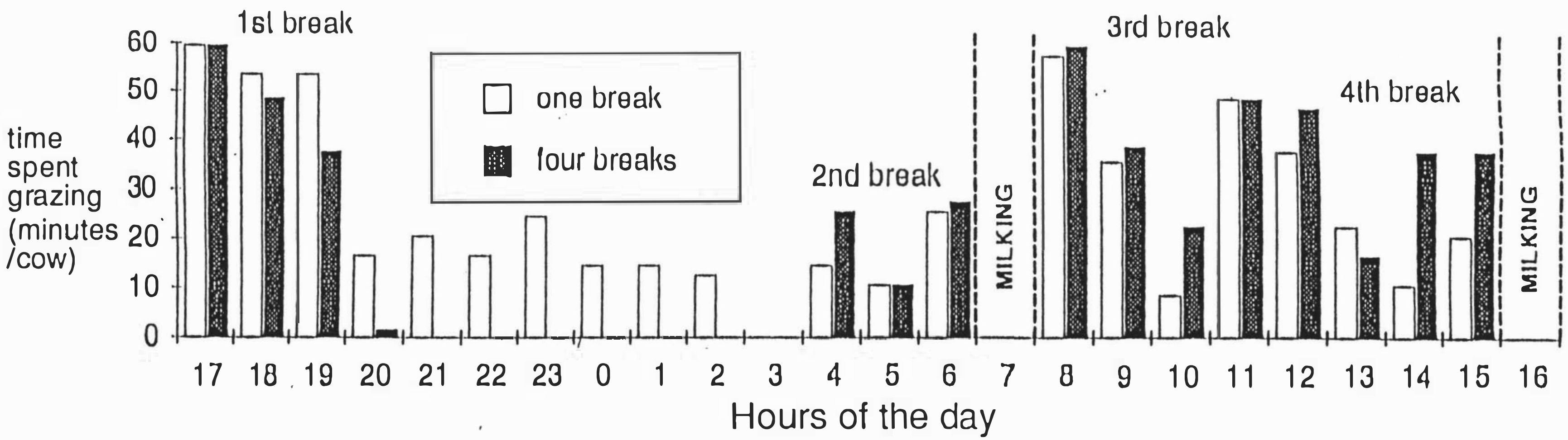



Figure 4.9 Proportion of each hour of the day spent grazing on 3rd-4th November 1986



## 4.2 HERBAGE MEASUREMENT, FEED INTAKE AND CHEMICAL ANALYSIS

### 4.2.1 HERBAGE MEASUREMENT AND FEED INTAKE

The mean values for the amounts of herbage mass and herbage allowance and herbage intake are presented in Table 4.14. Imposed herbage allowances were 30 and 40 kg DM/cow/day for period I and period II respectively. Table 4.14 shows actual levels of daily herbage allowance calculated retrospectively from the herbage cutting technique (Meijs 1981) results. Mean values of 29 and 30 kg DM/cow/day for the one break and four break respectively for period I were close to the imposed common pasture allowance. For period II, the mean daily values for HA were slightly higher than intended.

**Table 4.14 Mean herbage mass yields, herbage allowance and intakes for the treatment groups.**

| | 1 Break | 4 Breaks | SEM | Significance Levels |
|---|---|---|---|---|
| Pregrazing HM (kg DM/ha) | | | | |
| Period I | 2348 | 2360 | 60 | NS |
| Period II | 2525 | 2543 | 89 | NS |
| Residual HM (kg DM/ha) | | | | |
| Period I | 1425 | 1347 | 24 | NS |
| Period II | 1609 | 1703 | 25 | NS |
| HA (kg DM/cow/day) | | | | |
| Period I | 29 | 30 | 0.8 | NS |
| Period II | 44 | 45 | 0.9 | NS |
| DMI (kg DM/cow/day) | | | | |
| Period I | 12.3 | 11.8 | 0.9 | NS |
| Period II | 15.6 | 15.3 | 0.8 | NS |

§ least square means

There were no significant differences between treatments for any of these measurements (Table 4.14).

### 4.2.2. CHEMICAL ANALYSIS AND GROSS ENERGY DETERMINATION OF HERBAGE

It is reported here, with regrets, that the herbage samples which were preserved in the freezer awaiting chemical analyses disappeared while the author was on compassionate leave back home in Tanzania. Therefore results for chemical analyses are not available.

# Chapter 5

# DISCUSSION

## 5.1 THE EFFECTS OF FEEDING FREQUENCY ON INTAKE AND PRODUCTION

The output of milk from pasture depends upon the combined effects of the quality and quantity of pasture grown and the efficiencies with which the pasture is harvested and converted into milk by the grazing cow. In this respect pasture allowance is an important determinant of the intake and performance of grazing dairy cows. This has been demonstrated in many experiments for example Combellas and Hodgson (1979); Holmes *et al* (1979); Le Du *et al* (1979); Bryant (1980); Holmes and McClenaghan (1980), Glassey *et al* (1980), Meijs *et al* (1982) and Stockdale (1985). Some of the New Zealand studies have been reviewed by Holmes and Macmillan (1982) and Hodgson (1984). In all these experiments and reviews herbage allowances were given as one break per 24 hour period. However Hancock (1954a) and Flux and Patchell (1955) provided from 2 to 5 fresh areas (breaks) per 24 hours. In all cases with one break there were increases in intake with increases in herbage allowance and therefore in milk production. With 2 breaks (Hancock 1957a; Flux and Patchell 1955) or more (Flux and Patchell, 1955) there were influences in milk yield as will be discussed below.

### 5.1.1 HERBAGE ALLOWANCE DETERMINATION

Nominal planned value for herbage allowance was 30 kg DM/cow/day in Period I. The actual values were 29 and 30 kg DM/cow/day for 1B and 4B groups respectively.

In Period II the nominal herbage allowance was 40 kg DM/cow/day, while the actual values were 44 and 45 kg DM/cow/day for 1B and 4B groups respectively.

Therefore the herbage allowances actually offered were very close to the planned values.

### 5.1.2 EFFECTS OF TREATMENT ON PASTURE INTAKE IN RELATION TO HERBAGE ALLOWANCE

Apparent herbage intake was not affected by the treatment (Table 5.1). Mean values were 12.0 and 15.5 kg DM/cow/day in Periods I and II respectively. These values are similar to those reported by Holmes (1987) for HA of 30 and 40 kg DM/cow/day (figure 5.1) (assuming 450 kg liveweight/cow).

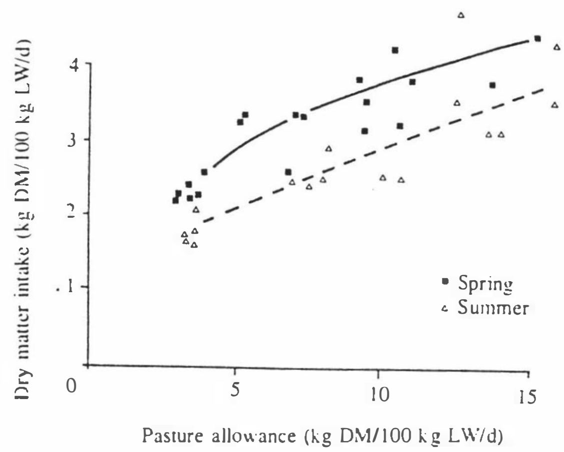
**Table 5.1: Mean herbage allowance and intakes for the treatment groups. §**

| | 1 Break | 4Breaks | SEM | Significance Levels |
|---|---|---|---|---|
| HA (kg DM/cow/day) | | | | |
| Period I | 29 | 30 | 0.8 | NS |
| Period II | 44 | 45 | 0.9 | NS |
| DMI (kg DM/cow/day) | | | | |
| Period I | 12.3 | 11.8 | 0.9 | NS |
| Period II | 15.6 | 15.3 | 0.8 | NS |

§ least square means

In the present study the pregrazed herbage mass ranged from 2300 - 2500 kg DM/ha. The nominal HA of 30 and 40 kg DM/cow/day were intended to provide equivalents of 6.5 and 8 kg DM/100 kg LW for Periods I and II respectively.

**Figure 5.1: Dry matter intake of lactating cows over a range of pasture allowances (from Holmes 1987).**




Note: Each point represents one treatment group. Pre-grazing pasture mass 2.0-2.5 and 2.1-5.4 kg DM/ha and digestibility of DM 74-78 and 64-74% in spring and summer respectively.

During Period I HA was 2.5 times the intake while during Period II the HA was thrice the intake.

The original plan was to offer 2 herbage allowances and 2 break frequency treatments in a 2 x 2 factorial design. The areas of pasture available and the number of cows required did not allow this to be done.

Ground conditions were wet during the present experiment in particular during Period I. This resulted in some pugging and soiling of the pasture. This resulted in rejection and hence wastage of herbage (Marsh and Campling, 1970; Brown and Evans, 1973).

The pugging and soiling was more pronounced and noticeable on the 4B treatment particularly on the 1st break because of the small area offered for this break. It is possible that had the experiment been carried out in drier conditions, the 4B treatment may have achieved higher intakes because of less pugging and soiling.

There do not appear to be any other experimental data (with more than one break) with which to compare the present results. Intake was not measured in the experiments with grazing cows carried out by Hancock (1954a) and by Flux and Patchell (1955). Hancock (1954a) did not actually determine intake but worked it out by the total time spent grazing and ruminating by the cows. Flux and Patchell (1955) did not make any measurements of pasture during their experiment.

No data are available for the digestibility of the pasture used in the present trial. However as the treatment groups were randomly assigned to separate halves of the same paddock it is logical to assume that the two groups consumed pasture of similar nutritive value. It is also assumed that other sward attributes such as green herbage mass (Holmes 1987) and botanical composition were similar in the allocated sward before grazing and hence the observed similar apparent intake (Hodgson 1984).

### 5.1.3 EFFECTS OF FEEDING FREQUENCY ON MILK PRODUCTION

Although some components tended to approach significance level ($p<0.05$) eg difference between lactose % during Period II, feeding frequency had no significant effect in most parameters observed.

#### 5.1.3.1 Yields of Milk, Milkfat, Milk Protein and Lactose

Relatively high levels of daily milk production were achieved throughout this experiment (21 to 23 kg milk per cow and 0.9 to 1.0 kg milkfat yield per cow).

Feeding frequency had no significant effects on yields of milk, fat, protein and lactose in either Period I or II. This contrasts with some other experiments with cows fed on roughage plus concentrates (eg Campbell and Merilan, 1961; Burt and Dunton, 1967; Wiktorson 1976 cited by Gibson 1984) but is similar (eg Burt and Dunton 1976; Thomas and Kelly, 1976; Gill and Castle, 1983; Sutton *et al* 1985) in milk yields. The results are also similar to those studies with grazing cows (Hancock 1954a; Flux and Patchell, 1955).

In addition it was not unexpected because of the lack of differences in intake between the two treatment groups. Herbage allowance was higher in Period II and small (non significant) differences in milk yields were recorded in Period II in favour of the 4B treatment. It is possible that frequent feeding may cause small increases in herbage intake and in milk yield if high values of herbage allowance are offered. This might happen because it is only at higher herbage allowance that herbage intake is no longer limited by quantity of pasture but by other factors (Le Du ***et al*** 1979; Bryant 1981; Hodgson 1984; Holmes 1987). Flux and Patchell (1955) also reported a small (non significant) difference in milk yield (0.22 kg/cow/day) in favour of 2B versus 1B although the amount of intake was not stated. One interesting feature was the increase of milk yield compared with the increase of lactose yield from PM to AM milking in both periods (Table 5.2). They were very closely similar in magnitude and pattern.

**Table 5.2: Comparison between PM and AM yield increased of milk relative to lactose (%).**

| Period of Analysis | | Treatment 1B | Treatment 4B |
|---|---|---|---|
| Period I | | | |
| % Increase (AM to PM) | Milk | 48 | 57 |
| | Lactose | 48 | 57 |
| Period II | | | |
| % Increase (AM to PM) | Milk | 52 | 62 |
| | Lactose | 53 | 62 |

The yields of lactose and milk at the AM milking were 1.6 times the yield at the PM milking for the 4B treatment group. The corresponding value for the 1B group was 1.5 times. The almost identical increases of lactose and milk for both Periods confirms the generally accepted fact that the yield of milk is closely related to the amount of lactose synthesized; this is because lactose is the major osmotically active constituent of milk (Sutton, 1981; Holmes and Wilson 1984; Mepham, 1987). In both periods the 4B treatment group produced more milk (Table 4.3) and lactose (Table 4.6) at the AM milking but less at the PM milking than the IB treatment group. However none of these differences was significant.

This small difference between the treatment groups may have been related to the differences in grazing behaviour (See Figures 4.8 and 4.9). The 4B group spent more time grazing during day time and less during the night time than the 1B group.

#### 5.1.3.2 Concentrations of Milkfat, Milk Protein and Lactose

Feeding frequency had no significant effect on composition except for lactose in Period II (Table 4.2c). The significant difference in lactose concentration has become apparent due mainly to the drop in the concentration for the 1B group while that of 4B remaining fairly constant (Table 4.2c). As metabolic or blood profiles were not determined it is difficult to explain this drop in concentration of lactose for the 1B (from Period I to II) in association to supply of lactose precursors. The supply of these precursors is influenced both by the digestive physiology of the cow and her endocrinological status (Sutton, 1981; Mepham, 1987).

### 5.1.4 CHANGE IN LIVEWEIGHT AND BODY CONDITION SCORE

The duration of the experiment was short. It lasted for 35 days and as such there was not much change in liveweight or body condition for both periods. Treatment effect was non significant, (as shown in Table 4.12) in all components for the two treatment groups.

## 5.2 THE EFFECTS OF FEEDING FREQUENCY ON GRAZING BEHAVIOUR

As there was no significant difference in herbage intake and many components of production these no positive responses might be explained by grazing behaviour responses.

There was no significant difference in total time spent grazing per 24 hours between the two treatment groups. This is in general agreement with the lack of differences in apparent intake although there is no necessary relation between grazing time and dry matter intake (Hancock, 1950, 1953; Amold, 1981; Arave *et al* 1982). In New Zealand no difference in grazing times were noted between cows of high and low breeding index (BI) in early and mid-season, but with late season and hence lactation high BI cows grazed significant longer (Arave and Kilgour 1982).

However there were differences between the treatment groups in relation to the time spent grazing during the day and night-time (see Table 4.13). The 4B group grazed less at night presumably because they did not have access to their entire grazing area at that time. But the 4B group grazed longer during day time presumably because they received fresh pasture in AM and PM whereas the 1B group received no fresh pasture at these times.

The circadian pattern of grazing and time spent grazing may change in response to sward characteristics and nutrient demand of the ruminant (Dulphy *et al*, 1980; Arnold, 1985; Hodgson, 1985) and these changes in grazing patterns may be seasonal or duirnal (Phillips and Leaver 1986). Therefore this might explain partly why the 4B group grazed more during the day time than the 1B group. Arnold (1985) observed that under intensive conditions and with a restricted food allowance animals fed whenever food was offered. Hancock (1953) also observed that cattle, given time will adapt their grazing habits to meet environmental conditions.

It is suggested, therefore, that the 4B group grazed longer during the day time than 1B to compensate for time lost during the night in order to meet their nutrient demands. These diurnal changes in grazing pattern and time spent grazing may be linked to differences in AM/PM yield characteristics in both periods.

## 5.3 EXPERIMENTAL DESIGN AND RELIABILITY OF METHOD FOR DETERMINING DRY MATTER YIELD AND INTAKE

### 5.3.1 LAYOUT OF EXPERIMENTAL AREA

The experimental area layout was good for the purpose of the trial. However an improvement could have been made by using more space to accommodate four groups in order to compare the effects of two levels of herbage allowance. This was not possible otherwise it would have interfered with the rest of the farm grazing operations. Two paddocks might have been needed for the four groups or one paddock with very narrow grazing space; which would have ended in disastrous results.

### 5.3.2 RELIABILITY OF THE HERBAGE CUTTING TECHNIQUE

As the experiment was simulating the grazing system of commercial farms it was not really necessary to determine intakes of individual cows. As mentioned earlier it would have been not possible to use the group information to infer individual cow performance. The method is suitable for strip grazing systems (Meijs *et al* 1982).

In comparing sward with animal methods, Stockdale and King (1983) recently concluded that pasture techniques were more likely to give reliable estimates of herbage intake of grazing dairy cows than the animal method. However the inaccuracy of the herbage cutting technique or 'difference' method can be put down to:-

(a) Sward 'Clumpiness' and Representative Sampling

The difference becomes increasingly inaccurate as grazing pressure decreases i.e. herbage allowance increases (Clark and Brougham, 1979). This is due to increased variability in herbage mass within the grazed area or 'clumpiness' particularly after grazing. More samples are required to accurately estimate herbage mass but this conflicts firstly with the physical limitation and time restraints of cutting large numbers of samples and secondly the need to ensure that the area harvested does not interfere with the experimental treatment (Michell 1982).

(b) Wet Conditions and Pugging of the Soil

High soil moisture is associated with increased inaccuracy of the difference method since there is a greater likelihood of herbage being trampled below ground level (Clark and Brougham 1979). Throughout the present experiment the soil was very wet and pugging was a problem particularly at the first break for the 4B group.

# Chapter 6

# CONCLUSION

After examining the consistently non significant results starting from pregrazing herbage mass, herbage allowances intake to grazing time through different components of production especially milk and milkfat it is tempting to draw bold conclusions. Before these conclusions are made it is believed that under drier conditions e.g. summer, pasture utilisation would have been greater but whether the treatment of feeding frequency would have any positive response is a different matter.

The cows used in this trial were physiologically responsive because they were at the first stage of lactation and high producing. They were offered equal amounts of pasture yet no significant difference was noted for milk yield, milkfat yield, lactose and other important components except lactose concentration in Period II, no significant difference in food intake; no significant difference in grazing time. Therefore imposing the treatments of one break or four breaks at common herbage allowance under similar conditions in this study is not important and not worth adopting.

A lot of inputs are required in terms of labour for fencing and removing the temporary fences to offer new breaks and in terms of fencing material as well as convenience of attending cows frequently.

The results are consistent with other people's studies including those done in New Zealand e.g. Hancock (1954a) and Flux and Patchell (1955) and those conducted in the northern hemisphere basing the diets on compound feeds.

# REFERENCES


ADAMS. G.B., JONES. R., and FORBES. J.M. (1983). Voluntary intake and growth of lambs offered fresh food one or four times per day. Animal Production. 36 - 508.

AGRICULTURAL RESEARCH COUNCIL 1980: The Nutrient Requirements of ruminant livestock. 2nd Edition. Commonwealth Agricultural Bureaux, Slough, United Kingdom. 351 pp

AGRICULTURAL RESEARCH COUNCIL. (1984). The Nutrient Requirements of Ruminant Livestock. Farnham Royal Commonwealth Agricultural Bureaux. 351 pp

ALLDEN. W.G. (1962). Rate of intake and grazing in relation to herbage availability. Proceedings of the Australian Society of Animal Production. 4. 163 - 166.

ALLDEN. W.G. and WHITTAKER. I.A.McD. (1970). The determinants of herbage intake by grazing sheep: the interrelationship of factors influencing herbage intake and availability. Australian Journal of Agricultural Research. **21**. 755 - 766.

ANGELONE. A., TOLEDO. J.M., and BURNS. J.C. (1980). Herbage measurement *in situ* by electronics. 1. The multiple-probe-type capacitance meter. A brief review. Grass and Forage Science. **35**. 25 - 33.

ANNISON. E.F., BICKERSTAFFE. R., and LINZEL. J.L. (1974). Glucose and fatty acid metabolism in cows producing milk of low fat content. Journal of Agricultural Science, Cambridge. **82**. 87 - 95.

ANNISON. E.F., GOODEN. J.M. and ODDY. V.H. (1982). Hormonal:Nutritional interactions in metabolic regulation in ruminants. Proceedings of Nutrition Society of Australia. 7. 81 - 88.

ARAVE. C.W., and ALBRIGHT. J.L. (1981). Cattle behaviour. Journal of Dairy Science. **64**. 1318 - 1329.

ARAVE. C.W., HURNIK. J.F. and FRIEND. T.H. (1984). Some observations on the role of behaviour in cattle production and future research needs. Applied Animal Ethology. **11**. 413 - 421.

ARAVE. C.W. and KILGOUR. R. (1982). Differences in grazing and milking behaviour in high and low breeding index cows. Proceedings of the New Zealand Society of Animal Production. **42**. 65 - 67.

ARMSTRONG. D.G. (1982). Digestion and utilisation of energy. In Nutritional Limits to Animal Production From Pastures. Edited by J.B. Hacker, Farnham Royal, CBA. pp 264 - 275.

BAILE. C.A. and DELLA-FERA. M.A. (1981). Nature of hunger and satiety control systems in ruminants. Journal of Dairy Science. **63**. 1140-1152.

BAILE. C.A. and DELLA-FERA. M.A. (1988). Physiology of control of food intake and regulation of energy balance in dairy cows. In: Nutrition and Lactation in the Dairy Cow. Edited by P.C. Garnsworthy, University of Nottingham School of Agriculture, Butterworths, London. pp 251-261.

BAILE. C.A. and FORBES. J.M. (1974). Control of feed intake and regulation of energy balance in ruminants. Physiology Review. **54**. 160 - 214.

BALCH. C.C. and CAMPLING. R.C. (1962). Regulating of voluntary food intake in ruminants. Nutrition Abstracts and Reviews. **32**. 669 - 686.

BALDWIN. B.A. (1985). Neural and hormonal mechanisms regulation food intake. Symposium on Food Intake and its Control by Farm Animals. Proceedings of the Nutrition Society. **44**. 308 - 311.

BALDWIN. R.L. and ALLISON. M.J. (1983). Rumen metabolism. Journal of Animal Science. **57**. 461 - 477.

BARNES. R.F. (1985). The savanna resource in ruminant production systems. Tropical Grasslands. **19**. 99 - 109.

BAUMAN. D.E., DAVIS. C.L. and BUCHOLTZ. H.F. (1971). Propionate production in the rumen of cows fed either a control or high grain, low fibre diet. Journal of Dairy Science. **54**. 1282 - 1287.

BAUMAN. D.E. and ELLIOT. J.M. (1983). Control of nutrient partitioning in lactating ruminants. Biochemistry of Lactation. Edited by T.B. Mepham. pp 437 - 468.

BAUMAN. D.E., MCCUTCHEON. S.N., STEINHOUR. W.D., EPPARD. P.J. and SECHEN. S.J. (1985). Sources of variation and prospects for improvement of productive efficiency in the dairy cow - a review. Journal of Animal Science. **60**. 583 - 592.

BAUMGARDT. B.R. (1970). Control of feed intake in the regulation of energy balance. In: Physiology of Digestion and Metabolism in the Ruminant. Proceedings of a 3rd International Symposium, Cambridge. Edited by A.T. Phillipson, Orel Press Limited, Newcastle Upon Tyne. pp 235 - 253.

BEEVER. D.E. and SIDDONS. R.C. (1986). Digestion and metabolism in the grazing ruminant. In: Control of Digestion and Metabolism in Ruminants. Edited by L.P. Milligan, W.L. Grovum and A. Dobson. pp 479 - 497.

BELL. F.R. (1971). Hypothalamic control of food intake. Symposium on "The Regulation of Voluntary Food Intake". Proceedings of the Nutrition Society. **30**. 103 - 109.

BINES. J.A. (1971). Metabolic and physical control of food intake in ruminants. Symposium on "The Regulation of Voluntary Food Intake". Proceedings of the Nutrition Society. **30**. 116 - 122.

BINES. J.A. (1976). Factors influencing voluntary food intake in cattle. In: Principles of Cattle Production. Edited by H. Swan and W.H. Broster, London, Butterworths. pp 287 - 305.

BINES. J.A., SUZUKI. S. and BALCH. C.C. (1969). The quantitative significance of long-term regulation of food intake in the cow. British Journal of Nutrition. **23**. 695 - 704.

BROOKES. I.M. (1982). An assessment of protein as a likely factor in the limitation of milk production of dairy cows grazing pasture. In: Dairy Production From Pasture. Edited by K.L. MacMillan and V.K. Taufa. pp 211 - 212.

BROOKES. I.M. and LANCASHIRE. J.A. (1979). Production of milk and milk components by cows grazing different ryegrass cultivars. Proceedings of the New Zealand Grassland Association. **41**. 123 - 129.

BROSTER. W.H. (1971). The effect of milk yield of the cow of the level of feeding before calving. Dairy Science Abstracts. **33**. 253 - 270.

BROSTER. W.H. (1972). Effect on milk yield of the cow of the level of feeding during lactation. Dairy Science Abstracts. **34**. 265 - 288.

BROSTER. W.H. (1974). Response of the dairy cow to level of feeding. National Institute for Research in Dairying. Biennial Review. pp 14-34.

BROSTER. W.H. (1976). Plane of nutrition for the dairy cow. In: Principles of Cattle Production. Edited by H. Swan and W.H. Broster, Butterworths, London. pp 271 - 285.

BROSTER. W.H. (1979). The role of the high yielding dairy cow. In: Feeding Strategy for the High Yielding Dairy Cow. Edited by W.H. Broster and H. Swan. pp 411 - 425.

BROSTER. W.H. and BROSTER. V.J. (1984). Reviews of the progress of dairy science: Long term of plane of nutrition on the performance of the dairy cow. Journal of Dairy Research. **51**. 149 - 196.

BROSTER. W.H. and STRICKLAND. M.J. (1977). Feeding the dairy cow in early lactation. ADAS Quarterly Review. **26**. 87 - 105.

BROSTER. W.H. and THOMAS. C. (1981). The influence of level and pattern of concentrate input on milk output. In: Recent Advances in Animal Nutrition. Edited by W. Haresign, Butterworths, London. pp 49 - 69.

BROWN. K.R. and EVANS. P.S. (1973). Animal treading - a review of the work of the late D.B. Edmond, New Zealand. Journal of Experimental Agriculture. **1**. 217 - 226.

BRYANT. A.M. (1980). Effect of herbage allowance on dairy cow performance. New Zealand Society of Animal Production. **40**. 50 - 58.

BRYANT. A.M. (1981). Maximising milk production from pasture. Proceedings of the New Zealand Grasslands Association. **42**. 82 - 91.

BRYANT. A.M. and TRIGG. T.E. (1979). Immediate and longer term response of dairy cows to level of nutrition in early lactation. Proceedings of New Zealand Society of Animal Production. **39**. 139 - 147.

BRYANT. A.M. and TRIGG. T.E. (1981). Progress report on the performance of Jersey cows differing in breeding index. Proceedings of the New Zealand Society of Animal Production. **41**. 39 - 43.

BRYANT. A.M. and TRIGG. T.E. (1982). The nutrition of the grazing dairy cow in early lactation. In: Dairy Production From Pasture. Edited by K.L. MacMillan and V.K. Vaufa. pp 185 - 207.

BULL. L.S., BAUMGARDT. B.R., and CLANCY. M. (1976). Influence of caloric density on energy intake by dairy cows. Journal of Dairy Science. 59. 1078 - 1086.

BURT. A.W.A. (1957). The influence of level of feeding during lactation upon the yield and composition of milk. Dairy Science Abstract. **19**. 435-453.

BURT. A.W.A. and DUNTON. C.R. (1967). Effect of frequency of feeding upon food utilisation by ruminants. Proceedings of Nutritional Society. **26.** 181 - 190.

BUTTERY. P.J. and FOULDS. A.N. (1985). Amino acid requirements of ruminants. In: Recent Advances in Animal Nutrition. Edited by W. Haresign and D.J.A. Cole. pp 257 - 271.

CAMPBELL. A.G. (1966). Pasture dry matter production and availability in a stocking rate and grazing management experiment with dairy cows. Journal of Agricultural Science. Cambridge. **67**. 199 - 210.

CAMPBELL. J.R. and MERILAN. C.P. (1961). Effects of frequency of feeding on production characteristics and feed utilisation in lactating dairy cows. Dairy Science. **44**. 664 - 671.

CAMPBELL. J.R., HOWE. W.M., MARTZ. F.A. and MERILAN. C.P. (1963). Effects of frequency of feeding on urea utilisation and growth characteristics in dairy heifers. Journal of Dairy Science. **46**. 131-134.

CAMPLING. R.C. (1970). Physiological regulation of voluntary intake. In: Physiology of Digestion and Metabolism in the Ruminant. Proceedings of a 3rd International Symposium, Cambridge. Edited by A.T. Phillipson, Orel Press Limited, Newcastle Upon Tyne. pp 226 - 234.

CAMPLING. R.C. (1975). Systems of grazing management for dairy cattle. In: Pasture Utilisation by the Grazing Animal. Edited by J. Hodgson and D.K. Jackson. pp 113 - 118.

CAMPLING. R.C. and MORGAN. C.A. (1981). Eating behaviour of housed dairy cows - a review. Dairy Science Abstracts. **43**. 57 - 63.

CAMMEL. S.B., THOMSON. D.J., BEEVER. D.E., HAINES. M.J. DHANOA. M.S. and SPOONER. M.C. (1986). The efficiency of energy utilisation in growing cattle consuming fresh perennial ryegrass (*Lolium perenne* cv Melle) or white clover (*Trifolium repens cv Blanca*). British Journal of Nutrition. **55**. 669 - 680.

CARRUTHERS. V.R. and BRYANT A.M. (1983). Evaluation of the use of Chromic Oxide to estimate the feed intake of dairy cows. New Zealand Journal of Agricultural Research. **26**. 183 - 186.

CHACON. E., STOBBS. T.H. and SANDLAND. R.L. (1976). Estimation of herbage consumption by grazing cattle using measurements of eating behaviour. Journal of British Grassland Society. **31**. 81 - 87.

CHAMBERLAIN. D.G. and THOMAS. P.C. (1983). A note on the use of Chromium Sesquioxide as a marker in nutritional experiments with dairy cows. Animal Production. **36**. 155 - 157.

CHENOST. M. and DEMARQUILLY. C. (1982). Measurement of herbage intake by housedanimals. In: Herbage Intake Handbook. Edited by J.D. Leaver, Maidenhead, Berks, British Grasslands Society. pp 95 - 112.

CHRISTIAN. K.R., WILLIAMS, V.J. and CARTER. A.H. (1965). The estimation of faeces output of stall-fed sheep using Chromic Oxide marker. New Zealand Journal of Agricultural Research. **8**. 530 - 541.

CLARK. B. and KEENER. H.A. (1962) Effect of frequent feeding on weight gain response in young dairy heifers. Journal of Dairy Science. **45**. 1199 - 1202.

CLARK. D.A. and BROUGHAM. R.W. (1979). Feed intake of grazing Friesian bulls. Proceedings of the New Zealand Society of Animal Production. **39**. 265 - 274.

COMBELLAS. J. and HODGSON. J. (1979). Herbage intake and milk production by grazing dairy cows. 1. The effects of variation in herbage mass and daily herbage allowance in a short term trial. Grass and Forage Science. **34**. 209 - 214.

CONRAD. H.R., PRATT. A.D. and HIBBS. J.W. (1964). Regulation of feed intake in dairy cows. 1. Change in importance of physical and physiological factors with increasing digestibility. Journal of Dairy Science. **47**. 54 - 62.

CORBETT. J.L. (1980). Grazing ruminants: Evaluation of their feeds and needs. Proceedings of New Zealand Society of Animal Production. **40**. 136 - 144.

CORBETT. J.L. (1981a). Measurement of the forage intake of grazing animals. In: Forage Evaluation Concepts and Techniques. Edited by J.L. Wheeler and R.D. Mochrie. pp 287 - 297.

CORBETT. J.L. (1981b). Determination of the utilisation of energy and nutrients by grazing animals. In: Forage Evaluation: Concepts and Techniques. Edited by J.L. Wheeler and R.D. Mochrie. pp 383 - 398.

CORBETT. J.L., GREENHALGH. J.F.D. and FLORENCE. E. (1960). Excretion of Chromium Sesquoxide administered as a component of paper to sheep. British Journal of Nutrition. **14**. 289 - 299.

CORBETT. J.L., LANGLANDS. J.P., MCDONALD. I. and PULLAR. J.D. (1966). Comparison by direct animal calorimetry of the net energy values of an early and late season growth of herbage. Animal Production. **8**. 13-27.

COTTA. M.A. and HEPSELL. R.B. (1986). Protein and amino acid metabolism of rumen bacteria. Control of Digestion and Metabolism in Ruminants. Edited by L.P. Milligan, W.L. Grovum, and A. Dobson. pp 122 - 136.

COWAN. R.T. (1985). Pasture and supplements in the sub-tropics and tropics. In: The Challenge Efficient Dairy Production. 1985. Dairy Production Conference. Australian Society of Animal Production. pp 109 - 117.

CRAMPTON. E.W. (1957). Interrelations between digestible nutrient and energy content, voluntary dry matter intake, and the overall feeding value of forages. Journal of Animal Science. **16**. 546 - 552.

CURLL. M.L. (1982). The grass and clover content of pastures grazed by sheep. Herbage Abstracts. **52**. 403 - 411.

DAVEY. A.W.F., GRAINGER. C., MACKENZIE. D.D.S., FLUX. D.S., WILSON. G.F., BROOKES. I.M. and HOLMES. C.W. (1983). Nutritional and physiological studies of differences between Friesian cows of high and low genetic merit. Proceedings of the New Zealand Society of Animal Production. **43**. 67 - 70.

DAVIS. C.L. and BROWN. R.E. (1970). Low milk fat syndrome. Physiology of Digestion and Metabolism in the Ruminant. Edited by A.T. Phillipson, Newcastle-upon Tyne. Oriel Press. pp 545 - 565.

DEJONG. A. (1986). The role of metabolites and hormones as feedbacks in the control of food intake in ruminants. Control of Digestion and Metabolism in Ruminants. Edited by L.P. Milligan, W.L. Grovum and A. Dobson. pp 459 - 478.

DIRKSEN. G. (1970). Acidosis. New Zealand Journal of Agricultural Research. **13**. 612 - 625.

DULPHY. J.P. and DEMARQUILLY.C. (1983). Voluntary feed consumption as an attribute of feeds. Feed Information and Animal Production. Edited by G. E. Robards and R.G. Packham. CAB. pp 135 - 156.

DULPHY. J.P., REMOND. B. and THERIEZ. M. (1980). Ingestive behaviour and related activities in ruminants. In: Digestive Physiology and Metabolism in Ruminants. Proceedings of the 5th International Symposium of Ruminant Physiology. Edited by Y. Ruckebusch and P. Thivend. Clermont, Feffand. pp 103 - 122.

ELLIS. K.J., LABY. R.H. COSTIGAN. P., ZIRKLER. K. and CHOICE. P.G. (1982). Continuous administration of Chromic Oxide to grazing cattle. Proceedings of Nutrition Society of Australia. 7. 177 Abstr.

ERFLE. J.D., SAUER. F.D. and MAHADEVAN. S. (1986). Energy metabolism in rumen microbes. In: Control of Digestion and Metabolism in Ruminants. Edited by L.P. Milligan, W.L. Grovum, and A. Dobson. pp 81 - 99.

ERNST. P., LE DU. Y.L.P. and CARLIER. L. (1980). Animal and sward production under rotational and continuous grazing management - a critical appraisal. Proceedings of the International Symposium of European Grassland Federation on the Role of Nitrogen in Intensive Grassland Production. Wageningen. pp 119 - 126.

FINN. J.D. (1974). A General Model for Multivariate Analysis. Holt Rinehart and Winston, Inc. New York.

FLETCHER. D.M., LANE. A.G., CAMPBELL. J.R. and MARTZ. F.A. (1968). Effect of multiple feeding upon performance of Guernsey heifers fed urea-treated corn silage. Journal of Dairy Science. **51.** 202 - 204.

FLUX. D.S. and PATCHELL (1955). A comparison of the milk porduction of cows on different systems of break feeding. New Zealand Journal of Science and Technology. **36**. 557 - 559.

FORBES. J.M. (1970). The voluntary food intake of pregnant and lactating ruminants: A review. The British Veterinary Journal. **126**. 1 - 11.

FORBES. J.M. (1971). Physiological changes affecting voluntary food intake in ruminants. Symposium on 'The Regulation of Voluntary Food Intake. Proceedings of the Nutrition Society. **30**. 135 - 142.

FORBES. J.M. (1980). Hormones and metabolites in the control of food intake. In: Digestive Physiology and Metabolism in Ruminants. Edited by Y. Ruckebusch and P. Thivend. pp 145 - 160.

FORBES. J.M. (1983). Physiology of regulation of food intake. In: Nutritional Physiology of Farm Animals. Edited by J.A.F. Rook and P.C. Thomas. pp 177 - 202.

FORBES. J.M. (1986a). The Voluntary Food Intake of Farm Animals. Butterworths, London. 206 pp.

FORBES. J.M. (1986b). Voluntary intake. In: Principles and Practice of Feeding Dairy Cows. Technical Bulletin 8. Edited by W.H. Broster, R.H. Phipps and C.L. Johnson. pp 11 - 24.

FORBES. J.M. (1986c). The effects of sex hormones, pregnancy and lactation on digestion, metabolism and voluntary food intake. Control of Digestion and Metabolism in Ruminants. Edited by L.P. Milligan, W.L. Grovum and A. Dobson. pp 420 - 435.

FORBES T.D.A. and HODGSON. J. (1985). Comparative studies of the influence of sward conditions on the ingestive behaviour of cows and sheep. Grass and Forage Science. **40**. 69 - 77.

FRAME. J. (1981). Herbage mass. In: Sward Measurement Handbook. Edited by J. Hodgson, R.D. Baker, Alison Davies, A.S. Laidlaw, and J.D. Leaver. BGS. pp 39 - 69.

FREER. M. (1981). The control of food intake by grazing animals. World Animal Science B.1. Grazing Animals. Edited by F.H.W. Morley. Amsterdam. Elsevier. pp 105 - 124.

GARRY. L.A., SHERRIT. G.W. and HALE. E.B. (1970). Behaviour of Charolais cattle on pasture. Journal of Agricultural Science. **30**. 203 - 206.

GIBB. M.J. and TREACHER T.T. (1983). The performance of lactating ewes offered diets containing different proportions of fresh perennial ryegrass and white clover. Animal Production. **37**. 433 - 440.

GIBSON. J.P. (1981). The effects of feeding frequency on the growth and efficiency of food utilisation of ruminants. An analysis of published results. Animal Production. **32**. 275 - 283.

GIBSON. J.P. (1984). The effects of frequency of feeding on milk production of dairy cattle. An analysis of published results. Animal Production. **38**. 181 - 189.

GILL. J.L. and HAFS. H.D. (1971). Analysis of repeated measurements of animals. Journal of Animal Science. **33**. 331 - 336.

GILL. M.S. and CASTLE. M.E. (1983). The effects of the frequency of feeding concentrates on milk production and eating behaviour in Ayrshire cows. Animal Production. **36**. 79 - 85.

GILL. M., ROOK. A.J., and THIAGO. L.R.S. (1988). Factors affecting the voluntary intake of roughages by the dairy cow. Nutrition and Lactation in the Dairy Cow. Edited by P.C. Garnsworthy, University of Nottingham School of Agriculture. Butterworths, London. pp 262 - 279.

GLASSEY. C.B., DAVEY. A.W.F. and HOLMES. C.W. (1980). The effect of herbage allowance on the dry matter intake and milk production of dairy cows. New Zealand Society of Animal Production. **40**. 59 - 63.

GORDON. J.F. (1976). Effect of concentrate level and stocking rate on performance of dairy cows calving in late winter. Animal Production. **22**. 175 - 187.

GORDON. J.G. and TRIBE. D.E. (1952). The importance to sheep of frequent feeding. British Journal of Nutrition. **6**. 89 -93.

GRAHAM. N.MCC. (1967). Effect of feeding frequency on energy and nitrogen balance in sheep given a ground and pelleted forage. Australian Journal of Research. **18**. 467 - 483.

GRAINGER. C., WILHEMS. G.D. and MCGOWAN. A.A. (1982). Effect of body condition at calving and level of feeding in early lactation of milk production of dairy cows. Australian Journal of Experimental Agriculture and Animal Husbandry. **22**. 9 - 17.

GRAINGER. C. and MCGOWAN. A.A. (1982). The significance of pre-calving nutrition of the dairy cow. Dairy Production From Pasture. Proceedings of the conference. edited by K.L. MacMillan and V.K. Taufa, New Zealand and Australia Societies of Animal Production, Hamilton. pp 134 - 171.

GRANT. S.A. and KING. J. (1984). Grazing management and pasture production: the importance of sward morphology adaptations and canopy photosynthesis. The Hill Farming Research Organisation Biennial Report 1982 - 1983. pp 119 - 129.

GREENHALGH. J.F.D. (1982). An introduction to herbage intake measurement. Herbage Intake Handbook. Edited by J.D. Leaver. pp 1 - 10.

GREENHALGH. J.F.D., REID. G.W. and AITKEN. J.N. (1966). The effects of grazing intensity on herbage consumption and animal production. 1. Short term effects in strip grazing dairy cows. Journal of Agricultural Science. **67**. 13 - 23.

HAFEZ. E.S.E. and LINDSAY. D.R. (1965). Behavioural responses in farm animals and their relevence to research techniques. Animal Breeding Abstracts. **33**. 1 - 16.

HANCOCK J. (1950). Grazing habits of dairy cows in New Zealand. Empire Journal of Experimental Agriculture. **18**. 249 - 263.

HANCOCK. J. (1953). Grazing behaviour of cattle. Animal Breeding Abstracts. **21**. 1 - 13.

HANCOCK. J. (1954a). Studies in grazing behaviour of dairy cattle. II Bloat in relation to grazing behaviour. Journal of Agricultural Science. **44**. 80 - 95.

HANCOCK. J. (1954b). Studies of grazing behaviour in relation to grassland management. I Variations in grazing habits of dairy cattle. Journal of Agricultural Science. **44**. 420 - 433.

HANCOCK. J.and MCMEEKAN. C.P. (1954). Studies of grazing behaviour in relation to grassland management III Rotational compared with continuous grazing. Journal of Agricultural Science. **44**. 96 - 103.

HARB. M.Y. and CAMPLING. R.C. (1985). Variation among pregnant non-lactating dairy cows in eating and ruminating behaviour, digestibility and voluntary intake of hay. Grass and Forage Science. **40**. 109 - 111.

HARESIGN. W. (1981). Body condition, milk yield and reproduction in cattle. Recent Developments in Ruminant Nutrition. Edited by W. Haresign and D.J.A. Cole. pp 1 - 16.

HODGSON. J. (1975). The influence of grazing pressure and stocking rate on herbage intake and animal performance. Pature Utilisation by the Grazing Animal. Edited by J. Hodgson and D.K. Jackson. pp 93 - 103.

HODGSON. J. (1977). Factors limiting herbage intake by the grazing animal. Proceedings of the International Meeting on Animal Production From Temperate Grasslands. Dublin. pp 70 - 75.

HODGSON. J. (1979). Nomenclature and definitions in grazing studies. Grass and Forage Science. **34**. 11 - 18.

HODGSON. J. (1981). Variations in the surface characteristics of the sward and the short term rate of herbage intake by calves and lambs. Grass and Forage Science. **36**. 49 - 57.

HODGSON. J. (1982a). Influence of sward characteristics on diet selection and herbage intake by the grazing animal. Nutritional Limits to Animal Production From Pasture. Edited by J.B. Hacker, Farnham Royal, C.A.B. pp 153 - 166.

HODGSON. J. (1982b). Ingestive behaviour. Herbage Intake Handbook. Edited by J.D. Leaver. pp 113 - 138.

HODGSON. J. (1984). Sward conditions, herbage allowance and animal production: an evaluation of research results. Proceedings of the New Zealand Society of Animal Production. **44**. 99 - 104.

HODGSON. J. (1985). The control of herbage intake in the grazing ruminant. Symposium on 'Food Intake and its Control by Farm Animals." Proceedings of the Nutrition Society. **44**. 339 - 346.

HODGSON. J. (1986) Grazing behaviour and herbage intake. Grazing: British Grassland Society Occassional Symposium. Edited by J. Frame. pp 51 - 64.

HODGSON. J. and JAMIESON. W.S. (1981). Variations in herbage mass and digestibility, and the grazing behaviour and herbage intake of adult cattle and weaned calves. Grass and Forage Science. **36**. 39 - 48.

HODGSON. J. and MAXWELL. J. (1982). Grazing research and grazing management. The Hill Farming Research Organisation: Biennial Report 1979 - 1981. Edited by R.G. Gunn. pp 169 - 187.

HODGSON. J. and RODRIGUEZ. J.M. (1970). The measurement of herbage intake in grazing studies. Grassland Research Institute Annual Report. Hurley. pp 132 - 140.

HOLMES. C.W. (1974). The Massey grass meter. Dairy Farming Annual. Edited by S.J. Rolston, D.C. Drummond, B.M. Williams and D.S. Flux. pp 26 - 30

HOLMES. C.W. (1987). Pastures for dairy cattle. Livestock Feeding on Pasture. Edited by A.M. Nicol. New Zealand Society of Animal Production, Ocassional Publication No. 10. pp 133 - 143.

HOLMES. C.W. (1988). Genetic merit and efficiency of milk production by the dairy cow. In: Nutrition and Lactation in the Dairy Cow. Edited by P.C. Garnsworthy, University of Nottingham School of Agriculture, Butterworths, London. pp 195 - 215.

HOLMES. C.W. and MACMILLAN. K.L. (1982). Nutritional management of the dairy herd grazing pasture. Dairy Production From Pasture. Edited by K.L. MacMillan and V.K. Taufa. pp 244 - 274.

HOLMES. C.W. and MCLENAGHAN. R. (1980). Feeding dry cows on grazed pastures during winter and changes in body condition. Dairy Farming Annual. pp 60 - 64.

HOLMES. C.W. and WILSON. G.F. (1984). Milk Production From Pasture. Butterworth New Zealand Limited. 319 pp.

HOLMES. C.W., DAVEY. A.W.F. and GRAINGER. C. (1981). The efficiency with which feed is utilised by the dairy cow. Proceedings of the New Zealand Society of Animal Production. **41**. 16 - 27.

HOLMES. C.W., MCLENAGHAN. R.J., AUKO. P. and NOTTINGHAM. R. (1979). The relation of pasture allowance to changes in body condition and weight of pregnant non-lactating cows. Proceedings of New Zealand Society of Animal Production. **39**. 138 - Abstr.

HOLMES. W. (1980). Grazing Management. Grass: Its Production and Utilisation. Edited by W. Holmes. Blackwell Scientific Publication, Oxford. pp 125 - 173.

HOLMES.W., CAMPLING. R.C. and JOSHI. N.D. (1972). A comparison between a rigid rotational grazing system for dairy cows and a system in which grazing is alternated with cutting. Animal Production. **14**. 283 - 294.

HOOGENDOORN. C.J. (1986). Studies of the effects of grazing regime on sward and dairy cow performance. Ph.D. Thesis. Massey University, Palmerston North, New Zealand.

HORTON. O.H. (1964). Influence of frequent feeding of grain on weight gain in dairy heifers. Journal of Dairy Science. **47**. 196 - 197.

HORTON. O.H. and NELSON. G.S. (1961). Frequency of grain feeding by mechanical means and growth rate response of dairy heifers. Journal of Dairy Science. **44**. 976 - Abstr.

HUGHES. T.P. (1983). Sward characteristics influencing intake. Lamb Growth Technical Handbook - Animal Industries Workshop June - July 1983. Edited by A.S. Familton, Lincoln College, Canterbury. pp 65 - 92.

HUTTON. J.B. (1963). The effect of lactation on intake in the dairy cow. Proceedings of the New Zealand Society of Animal Production. **23**. 39- 52.

JAMIESON, W.S. and HODGSON, J. (1979a). The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. Grass and Forage Science, **34**, 261-267.

JAMIESON, W.S. and HODGSON, J. (1979b). The effects of variation in sward characteristics upon the ingestive behaviour and herbage intake of calves and lambs under continuous stocking management. Grass and Forage Science, **34**, 273-282.

JOHNSON, C.L. (1986). Plane of nutrition. In Principles and Practice of Feeding Dairy Cows. Editors W.H. Broster, R.H. Phipps and C.L. Johnson. Technical Bulletin pp. 25-43.

JONES, D.I.H. and HAYWARDS, M.V. (1975). The effect of pepsin pre-treatment of herbage on the prediction of dry matter digestibility from solubility in fungal cellulose solution. Journal of the Science of Food and Agriculture, **26**, 711-718.

JOURNET, J. and REMOND, B. (1976): Physiological factors affecting the voluntary intake of feed by dairy cows. A review. Livestock Production Science, **3**, 129-146.

KAUFMANN. W. (1976). Influence of the composition of the ration and the feeding frequency on pH-regulation in the rumen and on feed intake in ruminants. Livestock Production Science. **3**. 103 - 114.

KAUFMANN. W. (1976). Influence or the compostion of the ration and feeding frequency on pH-regulating in the the rumen and on feed intake in ruminants. Livestock Production Science. **3**. 103 - 114.

KAUFMANN, W. and HAGEMEISTER, H. and DIRKSEN, G. (1980). Adaptation to changes in dietary composition level and frequency of feeding. In Digestive Physiology and metabolism in Ruminants. Edited by Ruckebusch and P. Thivend, pp. 587-602.

KILGOUR, R. (1985). Management behaviour. In Ethology of Farm Animals World Animal Science A5. Eidted by A.F. Frazer, Elsevier, Amsterdam, pp. 445-458.

KILGOUR, R. and DALTON, C. (1983). Livestock behaviour - a practical guide. Granada, London.

KING, K.R. and STOCKDALE, C.R. (1980). The effects of stocking rate and nitrogen fertilizer on the productivity of irrigated perennial pasture grazed by dairy cows. Australian Journal of Experimental Agriculture and Animal Husbandry, **20**, 537-542.

KIRCHGEBNER, M., MULLER, H.L. and SCHAWRZ, F.J. (1982). Experimental studies on the feeding frequency of dairy cows. In Energy Metabolism of Farm Animals. Editors A. Ekem and F. Sundstol, pp. 30-33.

KORTE, C.J. and SHEATH, G.W. (1978). Herbage dry matter production. The balance between growth and death. Proceedings of the New Zealand Grassland Association, **40**, 152-161.

KOTB, A.R. and LUCKEY, T.D. (1972). Markers in nutrition. Nutrition Abstracts and Reviews, **42**, 813-845.

LABY, R.H., GRAHAM, C.A., EDWARDS, S.R. and KAUTZNER, B. (1984). A controlled release intraruminal device for the administration of faecal dry-matter markers to the grazing ruminant. Candian Journal of Animal Science (Suppl), **64**, 337-338.

LAMBOURNE, L.J. and REARDON, T.F. (1963). The use of chromium oxide to estimate the faecal output of Merinos. Australian Journal of Research, **14**, 239-253.

LANGER, R.H.M. (1982). Growth of grasses and clovers. In Pastures and Pasture Plants. Editor R.H.M. Langer.

LANGLANDS, J.P. (1975). Techniques for estimating nutrient intake and its utilization by the grazing ruminant. In Digestion and Metabolism in the Ruminant. Edited by I.W. McDonald and A.C.I. Warner. Armidale, Australia, pp. 321-332.

LANGLANDS, J.P., CORBETT, J.L., McDONALD, I. and REID, G.W. (1963). Estimation of the faeces output of grazing animals from the concentration of chromium sesquioxide in a sample of faeces. 2. Comparison of estimates from samples taken at fixed times of day with estimates from samples from the sward. British Journal of Nutrition, **17**, 219-226.

LEAVER, J.D. (1983). Milk Production: Science and Practice. Longman, London and New York.

LEAVER, J.D. (1985). Milk production from grazed temperate grassland. Journal of Dairy Research, **52**: 313-344.

LE DU, Y.L., BAKER, R.D. and NEWBERRY, R.D. (1981). Herbage intake and milk production by grazing dairy cows. 3. The effect of grazing severity under continuous stocking. Grass and Forage Science, **36**: 307-318.

LE DU, Y.L., COMBELLAS, J., HODGSON, J. and BAKER, R.D. (1979). Herbage intake and milk production by grazing dairy cows. 2. The effects of level of winter feeding and daily herbage allowance. Grass and Forage Science, **34**: 249-260.

LE DU, Y.L. and HUTCHINSON, M. (1982). Grazing. In Milk from Grass. Edited by C. Thomas and J.W.O. Young Hurley. ICI/GRI, pp 43-57.

LEEK, B.F. (1986). Sensory receptors in the ruminant alimentary tract. In Control of Digestion and Metabolism in Ruminants. Edited by L.P. Milligan, W.L. Grovum and A. Dobson. Englewood Cliffs. Prentice-Hall, pp. 3-17.

LEEK, B.F. and HARDING, R.H. (1975). Sensory nervous receptors in the ruminant stomach and the reflex control of reticulo-ruminal motility. In Digestion and Metabolism in the Ruminant. Editors I.W. McDonald and A.C.I. Warner. Armidale, University of New England, pp. 60-76.

MCDONALD. I.W. (1948). The absorption of ammonia from the rumen of the sheep. Biochemical Journal. **49**. 586 - 587.

MacMILLAN, K.L., BRYANT, A.M. and DUGANZICH, D.M. (1982). Production differences associated with body condition score at calving and production index among cows in commercial herds. In Dairy Production from Pasture. Edited by K.L. MacMillan and V.K. Taufa, pp. 174-175.

MacRAE, J.C. (1983). The energy requirements of the lactating animal. In Recent Advanced in Animal Nutrition in Australia. Edited by D.J. Farrell and Pran Vohra, Armidale, pp. 23-34.

MCDONALD. I.W. (1948). The absorption of ammonia from the rumen of the sheep. Biochemistry Journal. **49**. 586 - 587.

McLAUGHLIN, C.L. (1982). Role of peptides from gastro-intestinal cells in food intake regulation. Journal of Animal Science, **55**: 1515-1527.

MARSH, R. and CAMPLING, R.C. (1970). Fouling of pastures by dung. Herbage Abstracts, **40**: 123-130.

MAYES, R.W., LAMB, C.S. and COLGROVE, P.M. (1986). The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. Journal of Agricultural Science, Cambridge, **107**: 161-170.

MEIJS, J.A.C. (1981). Herbage intake by grazing dairy cows. Centre for Agriculture and Documentation, Wageningen. 276 pp.

MEIJS, J.A.C. (1982). The effect of herbage mass and allowance upon herbage intake by grazing dairy cows. XIV International Grassland Congress, pp. 667-670.

MEIJS, J.A.C., WALTERS, R.J.K. and KEEN, A. (1982). Sward methods. In Herbage Intake Handbook. Edited by J.D. Leaver, pp. 11-36.

MEPHAM, T.B. (1987). Physiology of Lactation. University of Nottingham, Open University Press, Milton Keynes, Philadelphia, 207 pp.

MICHELL. P. (1982). Value of a rising plate meter for estimating herbage mass of grazed perennial ryegrass - white clover swards. Grass and Forage Science. **37**. 81 - 90.

MICHELL, P. and LARGE, R.V. (1983). The estimation of herbage mass of perennial ryegrass swards. A comparative evaluation of a rising-plate meter and a single-probe capacitance meter calibrated at and above ground level. Grass and Forage Science, **38**: 295-299.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1975). Energy allowances and feeding systems for ruminants. Technical Bulletin 33, H.M.S.O. London.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1984). Energy Allowances and Feeding Systems for Ruminants. Refeence Book 433, H.M.S.O. London.

MINSON, D.J. (1982). Effects of chemical and physical composition of herbage eaten upon intake. In Nutritional Limits to Animal Production from Pastures. Edited by J.B. Hacker. Farnham Royal, G.B.A., pp. 167-182.

MINSON, D.J. (1983). Forage quality: assessing the plant-animal complex. Proceedings of the XIV International Grasslands Congress June 15-24, 1981. Lexington, Kentucky, U.S.A., pp. 23-29.

MITCHELL, K.D. (1985). Effects of underfeeding in early lactation on yield and composition of milk produced by high and low breeding index cows. Thesis, M. Agr. Sc., Massey University, Palmerston North, New Zealand.

MOTT, G.O. (1982). Potential productivity of temperate and tropical grassland systems. Proceedings of the XIV International Grassland Congress, Lexington, U.S.A., pp. 35-42.

MUNRO. J.M.M. and WALTERS. R.J.K. (1986). The feeding value of grass. In: Grazing. Occasional Symposium No 19 British Grassland Society. Edited by J. Frame. pp 65 - 78.

ORSKOV, E.R. (1975). Manipulation of rumen fermentation for maximum food utilization. World Review of Nutrition and Dietics, **22**: 162-182.

ORSKOV. E.R. (1982). Protein Nutrition in Ruminants. Academic Press.

ORSKOV, E.R., GRUBB, D.A. and KAY, R.N.B. (1977). Effect of postruminal glucose or protein supplementation on milk yield and composition in friesian cows in early lactation and negative energy balance. British Journal of Nutrition, **38**: 397-405.

OSBOURN, D.F. (1980). The feeding value of grass and grass products. In Grass: Its Production and Utilisation. Edited by W. Holmes, BGS, Oxford. Blackwell, pp. 70-124.

PHILLIP. L.E., BUCHANAN-SMITH.J.G. and GROVUM (1980). Effect of ensiling whole plant corn on voluntary intake, rumen fermentation, retention time and rate of digestion in steers. Journal of Animal Science. **51**. 1003 - 1010.

PHILLIPS, C.J.C. and LEAVER, J.D. (1986). Seasonal and diurnal variation in the grazing behaviour of dairy cows. In Grazing: British Grassland Society Occasional Symposium No. 19. Edited by J. Frame. pp. 99-104.

POPPI, D.P., HUGHES, T.P. and L'HUILLIER, P.J. (1987). Intake of pasture by grazing ruminants. In Livestock Feeding on Pasture. Edited by A.M. Nicol. New Zealand Society of Animal Production, Occasional Publication No. 10, pp. 55-63.

RATTRAY, P.V. and JAGUSCH, K.J. (1978). Pasture allowance for the breeding ewe. Proceedings of the New Zealand Society of Animal Production, 38: 121-126.

RATTRAY, P.V. and JOYCE, J.P. (1974). Nutritive value of white clover and perennial ryegrass. New Zealand Journal of Agricultural Research, 17: 401-406.

REARDON, T.F. (1977). Effect of herbage per unit area and herbage allowance on dry matter intake by steers. Proceedings of the New Zealand Society of Animal Production, 37: 58-61.

REID. J.T., WHITE, O.D., ANRIQUE, R. and FORTIN, A. (1980). Nutritional energetics of livestock: some present boundaries of knowledge and future research needs. Journal of Animal Science, 51: 1393-1415.

ROBINSON, P.H. and SNIFFEN, C.J. (1985). Forestomach and whole tract digestibility for lactating dairy cows as influenced by feeding frequency. Journal of Dairy Science, 68: 857-867.

ROGERS, G.L., GRAINGER, C. and EARLE, D.F. (1979). Effect of nutrition of dairy cows in late pregnancy on milk production. Australian Journal of Experimental Agriculture and Animal Husbandry, 19: 7-12.

SCOTT, J.D.J. and SMEATON, D.C. (1980). In: Sheep and Cattle Nutrition (Eds J.D.J. Scott, N. Lamont, D.C. Smeaton and S.J. Hubson). Research Division, New Zealand Ministry of Agriculture and Fisheries, pp. 21-28.

SNIFFEN. C.J. and ROBISON. P.H. (1984). Nutritional strategy. Canadian Journal of Animal Science. 64. 529 - 542.

STAKELUM. G. (1986). Herbage intake of grazing dairy cows. 2. Effect of herbage allowance, herbage mass and concentrate feeding on the intake of cows grazing primary spring grass. Irish Journal of Agricultural Research. 25. 41 - 51.

STOBBS. T. H. (1973a). The effect of plant structure on the intake of tropical pastures. 1. Variation on the bite size of grazing cattle. Australian Journal of Agricultural Research. 24. 809 - 819.

STOBBS. T.H. (1973b). The effect of plant structure on the intake of tropical pastures. II. Differences in sward structure, nutritive value, and bite size of animals grazing *Setaria anceps* and *Chloris gayana* at various stages of growth. Australian Journal of Agricultural Research. 24. 821 - 829.

STOBBS. T.H. (1974a). Rate of biting by Jersey cows as influenced by yield and maturity of pasture swards. Tropical Grasslands. 8. 81 - 86.

STOBBS. T.H. (1974b). Components of grazing behaviour of dairy cows on some tropical and temperate pastures. Proceedings of the Australian Society of Animal Production. 10. 299 - 302.

STOBBS. T.H. (1975). Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. Tropical Grasslands. **9**. 141 - 150.

STEEL. R.G.D. and TORRIE. (1986). Principles and Procedures of Statistics: A Biometrical Approach. Fifth Edition. Macgraw-Hill International Book Company.

STOCKDALE. C.R. (1985). Influence of some sward characteristics on the consumption of irrigated pastures grazed by lactating dairy cattle. Grass and Forage Science. **40**. 31 - 39.

STOCKDALE. C.R. and KING. K.R. (1983). A comparison of two techniques used to estimate the herbage intake of lactating dairy cows in a grazing experiment. Journal of Agricultural Science, Cambridge. **100**. 227-230.

STOKES. M.R., BULL. L.S. and HALTMAN. W.A. (1985). Rumen liquid dilution rate in dairy cows fed once daily: Effects on diet and sodium bicarbonate supplementation. Journal of Dairy Science. **68**. 1171-1180.

STRICKLIN. W.R. and KAUTZ-SCANAVY. C.C. (1984). The role of behaviour in cattle production. A Review of Research. Applied Animal Ethology. **11**. 359 - 390.

SUTTON. J.D. (1980). Influence of nutritional factors on the yield and content of milkfat: Dietary components other than fat. Bull. Int. Dairy Fed. Docum. **125**. 126 - 134.

SUTTON. J.D. (1981). Concentrate feeding and milk composition. Recent Advances in Animal Nutrition. Edited by W. Haresign. pp 35 - 48.

SUTTON. J.D. (1985). Digestion and absorption of energy substrates in the lactating cow. Symposium: Energy nutrition and metabolism of the lactating cow. Journal of Dairy Science. **68**. 3376 - 3393.

SUTTON. J.D., BROSTER. W.H., NAPPER. D.J. and SIVITER. J.W. (1985). Feeding frequency for lactating cows: Effects on digestion, milk production and energy untilisation. British Journal of Nutrition. **53**. 117 - 130.

SUTTON. J.D., HART. I.C. and BROSTER. W.H. (1982). The effect of feeding frequency on energy metabolism in milking cows given low roughage diets. Energy Metabolism of Farm Animals. Editors A. Ekern and F Sundstol. pp 26 - 29.

SUTTON. J.D., HART. I.C., BROSTER. W.H. ELLIOT. ROSEMARY. J. and SCHULLER. E.S. (1986). Feeding frequency for lactating cows: Effect on rumen fermentation and blood metabolites and hormones. British Journal of Nutrition. **56**. 181 - 192.

THOMAS. H. (1980). Terminology and definitions in studies of grassland plants. Grass and Forage Science. **35**. 13 - 23.

THOMAS. P.C. and KELLY. M.E. (1976). The effect of frequency of feeding on milk secretion in the Aryshire cow. Journal of Dairy Research. **43**. 1 - 7.

THOMAS. P.C. and ROOK. J.A.F. (1981). Manipulation of rumen fermentation. Recent Developments in Ruminant Nutrition. Edited by W. Haresign and D.J.A. Cole. pp 157 - 183

THOMSON. D.J. (1979). Effect of the proportion of legumes in the sward on animal output: Changes in sward composition and productivity. Edited by A.H. Charles And R.J. Haggar. Hurley. British Grassland Society. pp 101 - 109.

THOMSON. D.J. (1984). The nutritive value of white clover. Forage legumes: Occasional Symposium No 16, BGS. Edited by D.J. Thomson. pp 78 - 91.

THOMSON. D. J., BEEVER. D.E., HAINES. M.J., CAMMELL. S.B., EVANS. R.T., DHANOA. M.S. and AUSTIN. A.R. (1985). Yiled and composition of milk from Friesian cows grazing either perennial ryegrass or white clover in early lactation. Journal of Dairy Research. **52**. 17 - 31.

THORNTON. R. F. (1987). The partitioning of nutrients by herbivores. Nutrtion of Herbivores. Second international symposium on the nutrition of herbivores. Edited by J. B. Hacker and J. H. Temouth, Academic Press, Australia. pp 307 - 331.

THORNTON. R.F. and MINSON. D.J. (1973). The relationship between apparent retention time in the rumen, voluntary intake, and apparent degestibility of legume and grass diets in sheep. Australian Journal of Agricultural Research. **24**. 889 - 898.

TILLEY. J.M.A. and TERRY. R.A. (1963). A two stage technique for the *in vitro* digestion of forage crops. Journal of British Grasslands Society. **18**. 104 - 111.

't MANNETJE. (1978). Measuring quantity of grassland vegetation. Measurement of Grassland Vegetation and Animal Production. edited by 't Mannetje. Bulletin Commonwealth Bureaux, Hurley, England. pp 63 - 95.

't MANNETJE. L. and EBERSOHN. J.P. (1980). Relations between sward characteristics and animal production. Tropical Grasslands. **14**. 273-279.

TRIGG. T.E., JURY. K.E., BRYANT. A.M. and PARR. C.R. (1980). The energy metabolism of dairy cows underfed in early lactation. Energy Metabolism: 8th Symposium Cambridge 1979. EAAP Publications No 26. Edited by L. E. Mount. Butterworth, London. pp 345 - 349.

TYRRELL. H.F. (1980). Limits to milk production efficiency by the dairy cow. Journal of Animal Science. **51**. 1441 - 1447.

ULYATT. M.J. (1971). Studies on the causes of the differences in pasture quality between perennial ryegrass, short rotation ryegrass, and white clover. New Zealand Journal of Agricultural Research. **14**. 352 - 367.

ULYATT,. M.J. (1973). The feeding value of herbage. Chemistry and Biochemistry of Herbage. Edited by G.W. Butler and R.W. Bailey. pp 131 - 178.

ULYATT. M.J., LANCASHIRE. J.A. and JONES. W.T. (1977). The nutritive value of legumes. Proceedings of the New Zealand Grassland Association. **38**. 107 - 118.

ULYATT. M.J., WAGHORN. G.C., JOHN. A., REID. C.S.W. and MONRO. J. (1984). Effect of intake and feeding frequency on feeding behaviour and quantitative aspects of digestion in sheep fed chaffed lucerne hay. Journal of Agricultural Science. Cambridge. **102**. 645 - 657.

UNDERWOOD. E.J. (1981). The Mineral Nutrition of Livestock 2nd Edition. Commonwealth Agricultural Bureaux, Farnham Royal, England.

VAN SOEST. P.J. (1982). Nutritional Ecology of the Ruminant. Corvallis, Oregon; O and B Books. 374 pp.

VERITE. R., REMOND. B. and JOURNETT. M. (1984). Sites of organic matter and protein digestion in lactating cows fed fresh grass from spring to autumn. Canadian Journal of Animal Science (suppl.). **64**. 328 - 329.

VICKERY. P.J. (1981). An improved capacitance meter for estimating herbage yield. Forage Evaluation: Concepts and Techniques. Edited by J.L. Sheeler and R.D. Mochrie, CSIRO, Australian and American Forage and Grassland Council, USA. pp 269 - 276.

VICKERY. P.J., BENNETT. I.L. and NICOL. G.R. (1980). An improved electronic capacitance meter for estimating herbage mass. Grass and Forage Science. **35**. 247 - 252.

WAGHORN. G.C. and BARRY. T.N. (1987). Pasture as a nutrient source. Livestock feeding on pasture. Edited by A.M. Nicol. New Zealand Society of Animal Production, Occasional Publication No. 10 pp 21 - 37.

WAITE. R., MACDONALD. W.B. and HOLMES. W. (1951). Studies in grazing management III The behaviour of dairy cows grazed under the close folding and rotational systems of management. Journal of Agricultural Science. **44**. 163 - 173.

WANYOIKE. M.M. and HOLMES. W. (1981). A comparison of indirect methods of estimating feed intake on pasture. Grass and Forage Science. **36**. 221 - 225.

WATKIN. B.R. and CLEMENTS. R.J. (1978). The effects of grazing animals on pastures. Plant Relations in Pastures. Edited by J.R. Wilson, CSIRO, Melbourne. pp 273 - 289.

WESTON. R.H. (1982). Animal factors affecting feed intake. Nutritional Limits to Animal Production From Pastures. Edited by J.B. Hacker, CAB, Farnham Royal, U.K. pp 183 - 198.

WHITEMAN. P.C. (1980). Tropical Pasture Science. Oxford Science Publication.

WILSON. G.F. (1967). Milk production from ryegrass varieties. Proceedings of the New Zealand Grassland Association. **29**. 102 - 110.

ZOBY. J.L.F. and HOLMES. W. (1983). The influence of size of animal and stocking rate on the herbage intake and grazing behaviour of cattle. Journal of Agricultural Science. Cambridge. **100**. 139 - 148.

MET. 301 (1982)

MINISTRY OF TRANSPORT – NEW ZEALAND METEOROLOGICAL SERVICE

# Daily Climatological Observations

Recorded at 0900 hours NZST + NZDT (............ G.M.T.)

| STATION No. | | | | | | YEAR | | MONTH | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| E | 0 | 5 | 3 | 6 | 3 | 8 | 6 | 1 | 0 |

Station: GRASLANDS D.V. DSIR PALM: NTH Lat.: 40 °23' S Long.: 175 °37' E Month: OCTOBER Year 19 86

HEIGHTS– Above MSL { Raingauge 33.52 m; Barometer ............ m }
Above Ground { Anemometer Head 5.49 m; Sunshine Recorder 4.57 m }

| DAY | Cloud Amount Eighths | Visibility Code | Surface Wind dd tens deg. (true) | Surface Wind f Beaufort | Gale | Snow | Snow Lying | Hail | Lightning | Thunder | Fog | Dew | Rainfall mm and tenths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 12 | 13 | 14 | 15 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 27 28 29 |
| 01 | 7 | 7 | 33 | 5 | | | | | | | | | .... |
| 02 | 8 | 6 | 31 | 6 | | | | | | | | | .... |
| 03 | 8 | 5 | 29 | 5 | | | | | | | | | 0079 |
| 04 | 8 | 5 | 29 | 4 | | | | | | | | | 0097 |
| 05 | 7 | 7 | 29 | 5 | | | | | | | | | 0099 |
| 06 | 8 | 6 | 09 | 2 | | | | | | | | | .... |
| 07 | 6 | 7 | 25 | 1 | | | | | | | | X | 0031 |
| 08 | 8 | 6 | 02 | 1 | | | | | | | | X | 0010 |
| 09 | 7 | 7 | 12 | 2 | | | | | | | | X | 0001 |
| 10 | 7 | 8 | 10 | 2 | | | | | | | | X | 0119 |
| 11 | 8 | 7 | 04 | 1 | | | | | X | | | X | 0108 |
| 12 | 8 | 6 | 04 | 1 | | | | | | | | | 0049 |
| 13 | 8 | 6 | 30 | 1 | | | | | | | | X | 0072 |
| 14 | 7 | 8 | 18 | 2 | | | | | | | | | 0042 |
| 15 | 3 | 8 | 00 | 0 | | | | | | | | X | 0017 |
| 16 | 8 | 7 | 14 | 1 | | | | | | | | | 0008 |
| 17 | 7 | 7 | 14 | 3 | | | | | | | | X | .... |
| 18 | 3 | 8 | 29 | 5 | | | | | | | | X | 0003 |
| 19 | 6 | 8 | 00 | 0 | | | | | | | | | 0048 |
| 20 | 2 | 9 | 31 | 1 | | | | | | | | X | .... |
| 21 | 8 | 7 | 04 | 2 | | | | | | | | X | 0142 |
| 22 | 8 | 6 | 27 | 5 | | | | | | | | | .... |
| 23 | 7 | 7 | 28 | 4 | | | | | | | | | 0021 |
| 24 | 8 | 5 | 00 | 0 | | | | | | | | | 0009 |
| 25 | 7 | 7 | 23 | 3 | | | | | | | | X | 0014 |
| 26 | 7 | 7 | 23 | 2 | | | | | | | | | 0011 |
| 27 | 5 | 7 | 29 | 6 | | | | | | | | X | 0097 |
| 28 | 2 | 7 | 28 | 2 | | | | | | | | X | .... |
| 29 | 8 | 6 | 29 | 3 | | | | | | | | X | .... |
| 30 | 1 | 8 | 09 | 3 | | | | | | | | X | .... |
| 31 | 7 | 7 | 28 | 1 | | | | | | | | X | .... |
| Sums | | | | | | | | | | | | | 1077 |
| Means | | | | | NOTE–Enter X to indicate occurrence. | | | | | | | | |

TEMPERATURES (Degrees and Tenths Celsius)

| DAY | Dry Bulb 0.1 | Wet Bulb 0.1 | Relative Humidity % | Max. 0.1 | Min. 0.1 | Grass Min. 0.1 | Earth 10 cm 0.1 | Earth 20 cm 0.1 | Earth 30 cm 0.1 | Earth 100 cm 0.1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 11 12 | 30 31 32 | 33 34 35 | | 36 37 38 | 39 40 41 | 42 43 44 | 45 46 47 | 48 49 50 | 51 52 53 | 54 55 56 |
| 01 | 128 | 104 | 73 | 154 | 091 | 066 | 113 | 117 | 123 | 123 |
| 02 | 130 | 102 | 68 | 153 | 114 | 103 | 117 | 120 | 124 | 119 |
| 03 | 136 | 126 | 88 | 154 | 120 | 110 | 122 | 122 | 124 | 119 |
| 04 | 148 | 145 | 96 | 171 | 133 | 127 | 135 | 130 | 128 | 121 |
| 05 | 157 | 135 | 77 | 171 | 130 | 125 | 138 | 134 | 133 | 121 |
| 06 | 121 | 110 | 86 | 147 | 090 | 084 | 130 | 132 | 135 | 124 |
| 07 | 114 | 093 | 74 | 146 | 047 | 006 | 108 | 115 | 125 | 124 |
| 08 | 112 | 109 | 96 | 145 | 096 | 090 | 126 | 128 | 131 | 124 |
| 09 | 139 | 108 | 66 | 178 | 108 | 074 | 131 | 129 | 133 | 125 |
| 10 | 145 | 133 | 86 | 187 | 107 | 082 | 134 | 134 | 136 | 125 |
| 11 | 142 | 137 | 94 | 179 | 121 | 108 | 142 | 140 | 143 | 128 |
| 12 | 140 | 132 | 90 | 187 | 113 | 077 | 145 | 143 | 144 | 129 |
| 13 | 131 | 116 | 82 | 169 | 107 | 094 | 147 | 145 | 146 | 130 |
| 14 | 130 | 115 | 82 | 161 | 096 | 090 | 140 | 140 | 144 | 131 |
| 15 | 127 | 108 | 78 | 178 | 072 | 022 | 130 | 135 | 141 | 137 |
| 16 | 123 | 114 | 89 | 183 | 074 | 030 | 132 | 136 | 144 | 133 |
| 17 | 138 | 112 | 71 | 166 | 090 | 052 | 127 | 130 | 138 | 134 |
| 18 | 135 | 100 | 61 | 164 | 101 | 085 | 125 | 134 | 140 | 135 |
| 19 | 120 | 101 | 77 | 152 | 052 | 013 | 121 | 128 | 138 | 135 |
| 20 | 123 | 098 | 70 | 167 | 047 | 007 | 121 | 127 | 137 | 136 |
| 21 | 156 | 120 | 63 | 168 | 100 | 053 | 141 | 141 | 145 | 136 |
| 22 | 136 | 115 | 76 | 157 | 106 | 101 | 130 | 134 | 141 | 136 |
| 23 | 146 | 120 | 72 | 164 | 102 | 076 | 133 | 134 | 140 | 137 |
| 24 | 132 | 127 | 94 | 178 | 112 | 098 | 133 | 135 | 140 | 137 |
| 25 | 151 | 147 | 95 | 163 | 126 | 133 | 150 | 147 | 147 | 137 |
| 26 | 134 | 120 | 83 | 177 | 111 | 090 | 137 | 142 | 146 | 138 |
| 27 | 145 | 125 | 78 | 170 | 116 | 096 | 140 | 147 | 150 | 139 |
| 28 | 127 | 105 | 74 | 177 | 093 | 054 | 128 | 138 | 147 | 140 |
| 29 | 128 | 115 | 84 | 176 | 077 | 032 | 135 | 141 | 147 | 139 |
| 30 | 139 | 110 | 68 | 192 | 103 | 077 | 129 | 139 | 148 | 141 |
| 31 | 142 | 126 | 82 | 193 | 083 | 037 | 140 | 143 | 150 | 142 |
| Sums | 4475 | 3628 | 2473 | 5227 | 3038 | 2292 | 4080 | 4160 | 4308 | 4075 |
| Means | 135 | 117 | 80 | 169 | 098 | 074 | 132 | 134 | 139 | 131 |

| DAY | Press. MSL at Observation Hour 0.1 mb | Sunshine Total for the Day Hours and Tenths: As Evaluated | Adjusted | Radiation *Langleys *0.1 MJ m² | Wind from Anemometer Total Run *km 09–09 | Maximum Gust (kt) 00–24 DD | FF | Evaporation Raised Pan* 0.1 mm | Snow Depth Fresh cm | Snow Depth Total cm | Weather at 9 a.m. | 00–06 | 06–12 | 12–18 | 18–24 | DAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 12 | 57 58 59 | | 60 61 62 | 63 64 65 | 66 67 68 | 69 70 | 71 72 | 73 74 75 | — | — | — | — | — | — | — | |
| 01 | | 031 | | | 520 | | | 038 | | | c | c | c | bc | c | 01 |
| 02 | | 009 | | | 677 | | | 031 | | | o | c | o-c | o | o-c | 02 |
| 03 | | 000 | | | 659 | | | 004 | | | o | o | o-c | c-o | o | 03 |
| 04 | | 000 | | | 332 | | | 005 | | | or | $or^{0}$ | $or^{1}$ | o | op | 04 |
| 05 | | 025 | | | 407 | | | 021 | | | c | $or^{0}$ | $or^{1}$ | cp | $cr^{0}$ | 05 |
| 06 | | 001 | | | 202 | | | 020 | | | o | $or^{2}$ | $or^{0}$ | o | o | 06 |
| 07 | | 028 | | | 101 | | | 009 | | | c | c | c-bc | c | op | 07 |
| 08 | | 000 | | | 147 | | | 008 | | | o | op | $or^{1}$ | op | o | 08 |
| 09 | | 080 | | | 275 | | | 046 | | | c | c | c-bc | bc | bc-c | 09 |
| 10 | | 028 | | | 197 | | | 009 | | | c | c | cp | bc-cp | $cr^{1}$ | 10 |
| 11 | | 011 | | | 121 | | | 008 | | | o | $or^{1}$ | $or^{2}$ | c-$or^{2}$ | $or^{2}$ | 11 |
| 12 | | 019 | | | 101 | | | 019 | | | o | $or^{0}$ | $or^{2}c$ | $or^{2}c$ | $or^{0}$ | 12 |
| 13 | | 004 | | | 099 | | | 011 | | | o | o | o-c | c-$or^{2}$ | $or^{0}$ | 13 |
| 14 | | 019 | | | 087 | | | 012 | | | c | $or^{1}$-$pr^{2}$ | c-bc | bc-$cr^{2}$ | bc | 14 |
| 15 | | 105 | | | 125 | | | 032 | | | bc | b | b-bc | bc | bc | 15 |
| 16 | | 010 | | | 243 | | | 019 | | | $or^{0}$ | $opr^{2}$ | $or^{1}pr^{2}$ | $opr^{2}$-c | c | 16 |
| 17 | | 059 | | | 649 | | | 040 | | | c | c | c-o | c-bc | bc | 17 |
| 18 | | 036 | | | 183 | | | 031 | | | bc | b-bc | bc-c | cp-bc | cp | 18 |
| 19 | | 000 | | | 135 | | | 013 | | | c | c | o | $or^{1}$ | $or^{1}$ | 19 |
| 20 | | 113 | | | 115 | | | 039 | | | bc | cp | bc | bc | bc | 20 |
| 21 | | 000 | | | 428 | | | 027 | | | o | bc-o | $or^{1}$ | $or^{1}$ | or | 21 |
| 22 | | 063 | | | 528 | | | 052 | | | o | op | o-bc | b | c | 22 |
| 23 | | 050 | | | 354 | | | 034 | | | c | bc | c-bc | o | o | 23 |
| 24 | | 000 | | | 156 | | | 007 | | | o | o | $or^{0}$ | $or^{1}$ | o | 24 |
| 25 | | 000 | | | 269 | | | 016 | | | o | o | o | $orpr^{2}$ | o | 25 |
| 26 | | 084 | | | 373 | | | 036 | | | c | c | bc-c | bc | bc | 26 |
| 27 | | 049 | | | 405 | | | 040 | | | c | $cpr^{2}$ | $cpr^{2}$ | c-bc | $cr^{1}$-$r^{2}$ | 27 |
| 28 | | 085 | | | 165 | | | 031 | | | bc | c | bc | bc | b | 28 |
| 29 | | 030 | | | 269 | | | 035 | | | o | b-c | c-o-c | c | c-b | 29 |
| 30 | | 085 | | | 211 | | | 050 | | | b | b | b | bc | bc | 30 |
| 31 | | 095 | | | 169 | | | 060 | | | c | c | c-bc | bc | bc | 31 |
| Sums | | 1119 | | | 8702 | | | 803 | | | | | | | | |
| Means | | | | | 281 | | | | | | | | | | | |

*Delete type not applicable

ENTER REMARKS and STOCK & CROP NOTES on BACK of FORM

**MONTHLY SUMMARY–**

Highest daily rainfall 14.2 mm on 21st
No. of days with rain ≥ 0.1 mm 21
No. of days with rain ≥ 1.0 mm 17

Highest pressure — ............ mb on ............
Lowest pressure — ............ mb on ............

No. of days with screen frost (Screen min. below 0°C) –
No. of days with ground frost (Grass min. –1.0°C or lower) –

Mean Vapour Pressure ............ mb
Mean temperature ½ (max. + min.) 13.4 °C
Range (mean max. – mean min.) 7.1 °C
Highest Maximum 19.3 °C on 31st
Lowest Minimum 4.7 °C on 7+20th
Lowest Maximum 14.5 °C on 8th
Highest Minimum 13.3 °C on 4th
Lowest Grass Minimum 0.6 °C on 7th
Highest Gust ............ knots, from ............ °T on ............
Highest daily wind run 677 *miles/kilometres on 2nd

WIND SUMMARY: Number of Observations

| Force ≥8 | Force 4–7 | 34/02 | 03/06 | 07/11 | 12/15 | 16/20 | 21/24 | 25/29 | 30/33 | Calm | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| – | 9 | 1 | 3 | 3 | 3 | 1 | 2 | 11 | 4 | 3 | 31 |

Signed: [signature] Observer.

NOTES–1. For instructions on completion of form refer to N.Z. Met. Service Misc. Publication 102.
2. Rainfall, Maximum Temperature, Evaporation and Wind Kilometres Run, read at 9 a.m., must be entered to PREVIOUS day.

M.O. USE ONLY

Site change noted. Date: ............
Evaporimeter type code: ............

| Data Checks | Additions and Means | Computer Edit Checks | Gazette |
|---|---|---|---|
| | | | |

MINISTRY OF TRANSPORT – NEW ZEALAND METEOROLOGICAL SERVICE

MET. 301 (1982)

## Daily Climatological Observations

Recorded at 0900 hours NZDT (............. G.M.T.)

| STATION No. | | | | | | YEAR | | MONTH | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| E | 0 | 5 | 3 | 6 | 3 | 8 | 6 | 1 | 1 |

Station: GRASSLANDS DIV DSIR P.N. Lat.: 40 °23 'S Long.: 175 °37 'E Month: NOVEMBER Year 19 86

HEIGHTS– Above MSL { Raingauge 33.52 m; Barometer ........ m } Above Ground { Anemometer Head 5.49 m; Sunshine Recorder 4.57 m }

| DAY | Cloud Amount (eighths) | Visibility Code | Surface Wind dd tens deg. (true) | Surface Wind f Beaufort | Gale | Snow | Snow Lying | Hail | Lightning | Thunder | Fog | Dew | Rainfall mm and tenths | Dry Bulb 0.1 | Wet Bulb 0.1 | Relative Humidity % | Max. 0.1 | Min. 0.1 | Grass Min. 0.1 | Earth 10 cm 0.1 | Earth 20 cm 0.1 | Earth 30 cm 0.1 | Earth 100 cm 0.1 | Press. MSL at Observation Hour 0.1 mb | Sunshine Total for the Day Hours and Tenths As Evaluated | Sunshine Adjusted | Radiation *Langleys *0.1 MJ m² | Wind from Anemometer *Total Run *km 09–09 | Maximum Gust (kt) 00–24 DD | Maximum Gust (kt) 00–24 FF | Evaporation Raised Pan* 0.1 mm | Snow Depth Fresh cm | Snow Depth Total cm | Weather at 9 a.m. | During 24 Hours 00–06 | 06–12 | 12–18 | 18–24 | DAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 12 | 13 | 14 | 15 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 27 28 29 | 30 31 32 | 33 34 35 | | 36 37 38 | 39 40 41 | 42 43 44 | 45 46 47 | 48 49 50 | 51 52 53 | 54 55 56 | 57 58 59 | | 60 61 62 | 63 64 65 | 66 67 68 | 69 70 | 71 72 | 73 74 75 | — | — | — | | | | | |
| 01 | 7 | 8 | 14 | 2 | | | | | | | | X | .... | 147 | 133 | 84 | 175 | 134 | 093 | 157 | 159 | 160 | 143 | | 010 | | | 263 | | | 028 | | | c | c | c | c-bc | c | 01 |
| 02 | 8 | 8 | 34 | 4 | | | | | | | | | 0029 | 144 | 114 | 67 | 187 | 105 | 080 | 144 | 147 | 157 | 143 | | 036 | | | 297 | | | 038 | | | o | o | o | c | cr | 02 |
| 03 | 6 | 7 | 31 | 4 | | | | | | | | √ | 0002 | 150 | 126 | 74 | 171 | 120 | 109 | 150 | 154 | 158 | 144 | | 052 | | | 288 | | | 031 | | | c | orpl$^2$ | cpl$^2$ | cp$^2$-bc | c | 03 |
| 04 | 8 | 7 | 00 | 0 | | | | | | | | | .... | 120 | 102 | 78 | 170 | 083 | 047 | 137 | 146 | 153 | 145 | | 015 | | | 115 | | | 025 | | | o | o | c | c- | c | 04 |
| 05 | 6 | 7 | 31 | 1 | | | | | | | | | .... | 144 | 115 | 68 | 204 | 093 | 069 | 143 | 148 | 152 | 146 | | 087 | | | 134 | | | 045 | | | c | c | c-bc | bc | bc | 05 |
| 06 | 4 | 8 | 25 | 1 | | | | | | | | | .... | 146 | 131 | 83 | 220 | 083 | 053 | 150 | 156 | 161 | 146 | | 093 | | | 178 | | | 049 | | | bc | bc | bc | b | bc | 06 |
| 07 | 8 | 6 | 22 | 1 | | | | | | | | | .... | 149 | 143 | 93 | 183 | 135 | 136 | 174 | 176 | 175 | 147 | | 029 | | | 427 | | | 045 | | | o | o | c | c | bc | 07 |
| 08 | 7 | 7 | 23 | 5 | | | | | | | | X | 0006 | 155 | 145 | 89 | 180 | 134 | 120 | 159 | 160 | 168 | 148 | | 010 | | | 487 | | | 026 | | | c | c | c | c | c | 08 |
| 09 | 6 | 8 | 23 | 3 | | | | | | | | | .... | 153 | 141 | 86 | 191 | 133 | 128 | 155 | 159 | 163 | 150 | | 073 | | | 337 | | | 051 | | | c | cr° | c-bc | bc | bc | 09 |
| 10 | 6 | 7 | 31 | 3 | | | | | | | | X | .... | 154 | 122 | 66 | 196 | 122 | 120 | 162 | 166 | 168 | 151 | | 049 | | | 307 | | | 048 | | | c | c | c | c | c | 10 |
| 11 | 8 | 7 | 31 | 4 | | | | | | | | | 0003 | 137 | 110 | 70 | 187 | 123 | 118 | 157 | 168 | 173 | 152 | | 030 | | | 269 | | | 037 | | | o | o | o-c | c-bc | cp | 11 |
| 12 | 8 | 8 | 32 | 2 | | | | | | | | | 0013 | 171 | 148 | 76 | 197 | 124 | 090 | 164 | 166 | 170 | 153 | | 018 | | | 622 | | | 036 | | | o | o | o | or'c | c | 12 |
| 13 | 8 | 6 | 28 | 5 | | | | | | | | | 0007 | 120 | 105 | 82 | 161 | 111 | 087 | 134 | 148 | 158 | 154 | | 095 | | | 772 | | | 079 | | | or | c | cr° | bc | bc | 13 |
| 14 | 8 | 6 | 25 | 6 | | | | | | | | | 0029 | 147 | 120 | 71 | 173 | 106 | 083 | 138 | 147 | 156 | 154 | | 038 | | | 493 | | | 039 | | | o | o | o-c | c-bc | bc-c | 14 |
| 15 | 8 | 8 | 11 | 4 | | | | | | | | | .... | 120 | 100 | 76 | 158 | 094 | 085 | 138 | 149 | 156 | 155 | | 046 | | | 365 | | | 060 | | | o | or° | o | o-bc | bc | 15 |
| 16 | 7 | 6 | 04 | 2 | | | | | | | | | .... | 133 | 116 | 80 | 206 | 093 | 065 | 134 | 144 | 153 | 153 | | 085 | | | 147 | | | 035 | | | c | c | c-bc | bc | bc | 16 |
| 17 | 7 | 7 | 34 | 2 | | | | | | | | | .... | 162 | 143 | 80 | 201 | 101 | 066 | 158 | 162 | 164 | 154 | | 090 | | | 221 | | | 054 | | | c | c | c | c-bc | c | 17 |
| 18 | 3 | 7 | 09 | 1 | | | | | | | | | .... | 148 | 126 | 76 | 187 | 090 | 048 | 154 | 166 | 169 | 155 | | 069 | | | 351 | | | 062 | | | bc | bc | bc | bc | c | 18 |
| 19 | 7 | 7 | 14 | 2 | | | | | | | | | .... | 122 | 092 | 64 | 157 | 103 | 086 | 150 | 163 | 168 | 155 | | 033 | | | 267 | | | 054 | | | c | c | c | c | c-bc | 19 |
| 20 | 5 | 8 | 16 | 2 | | | | | | | | | .... | 132 | 090 | 53 | 168 | 058 | 036 | 139 | 150 | 160 | 156 | | 088 | | | 263 | | | 048 | | | c | c | c | c-bc | bc | 20 |
| 21 | 5 | 8 | 10 | 2 | | | | | | | | | .... | 129 | 098 | 64 | 197 | 057 | -003 | 131 | 147 | 157 | 156 | | 106 | | | 381 | | | 067 | | | c | c | c | bc | bc | 21 |
| 22 | 1 | 9 | 11 | 4 | | | | | | | | | .... | 136 | 105 | 66 | 249 | 090 | 058 | 140 | 155 | 163 | 156 | | 125 | | | 166 | | | 065 | | | b | b | b | b | b | 22 |
| 23 | 4 | 7 | 31 | 2 | | | | | | | | | 0019 | 180 | 147 | 68 | 218 | 090 | 050 | 165 | 173 | 175 | 157 | | 012 | | | 173 | | | 028 | | | bc | bc | bc-cr° | c | cr° | 23 |
| 24 | 8 | 6 | 02 | 2 | | | | | | | | | 0046 | 167 | 147 | 79 | 187 | 126 | 105 | 166 | 171 | 173 | 156 | | 002 | | | 271 | | | 012 | | | o | o | opl$^2$ | cpr$^2$ | cpl$^2$ | 24 |
| 25 | 7 | 8 | 34 | 3 | | | | | | | | | 0026 | 144 | 120 | 75 | 181 | 086 | 053 | 139 | 149 | 159 | 157 | | 033 | | | 231 | | | 026 | | | c | c | c | cr' | o | 25 |
| 26 | 8 | 7 | 23 | 2 | | | | | | | | | 0010 | 116 | 109 | 91 | 175 | 106 | 083 | 142 | 153 | 159 | 157 | | 005 | | | 153 | | | 022 | | | o | o'pl$^2$ | o | cpx$^2$ | c | 26 |
| 27 | 8 | 6 | 00 | 0 | | | | | | | | | 0015 | 127 | 116 | 84 | 172 | 102 | 065 | 147 | 153 | 159 | 157 | | 013 | | | 298 | | | 027 | | | od | o | op | o-cp | c | 27 |
| 28 | 8 | 7 | 31 | 4 | | | | | | | | | 0005 | 130 | 123 | 91 | 191 | 118 | 115 | 150 | 157 | 162 | 157 | | 023 | | | 508 | | | 065 | | | o | op | op | c | cpr° | 28 |
| 29 | 5 | 7 | 23 | 4 | | | | | | | | | .... | 146 | 103 | 53 | 173 | 100 | 075 | 135 | 148 | 167 | 156 | | 126 | | | 399 | | | 060 | | | c | o | c-bc | bc | bc | 29 |
| 30 | 6 | 7 | 04 | 2 | | | | | | | | | 0107 | 143 | 118 | 72 | 158 | 062 | 019 | 134 | 147 | 158 | 158 | | 001 | | | 253 | | | 008 | | | c | c | c-o | or° | or° | 30 |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 31 |
| Sums | | | | | | | | | | | | | 0317 | 4272 | 3608 | 2259 | 5573 | 3082 | 2339 | 4446 | 4687 | 4821 | 4571 | | 1492 | | | 9436 | | | 1270 | | | | | | | | |
| Means | | | | | | | | | | | | | | 142 | 120 | 75 | 186 | 103 | 078 | 148 | 156 | 162 | 152 | | | | | 315 | | | | | | | | | | | |

NOTE–Enter X to indicate occurrence.

*Delete type not applicable

ENTER REMARKS and STOCK & CROP NOTES on BACK of FORM

### MONTHLY SUMMARY–

Highest daily rainfall 10.7 mm on 30th
No. of days with rain ≥ 0.1 mm 14
No. of days with rain ≥ 1.0 mm 9

Highest pressure ____ ........ mb on ........
Lowest pressure ____ ........ mb on ........

No. of days with screen frost (Screen min. below 0° C) –
No. of days with ground frost (Grass min. –1.0°C or lower) –

Mean Vapour Pressure ........ mb
Mean temperature ½ (max. + min.) 14.5 °C
Range (mean max. – mean min.) 8.3 °C
Highest Maximum 24.9 °C on 22nd
Lowest Minimum 5.7 °C on 21st
Lowest Maximum 15.7 °C on 19th
Highest Minimum 13.5 °C on 7th
Lowest Grass Minimum –0.3 °C on 21st
Highest Gust ........ knots, from ........ °T on ........
Highest daily wind run 772 *miles/kilometres on 13th

WIND SUMMARY: Number of Observations

| Force ≥8 | Force 4–7 | 34/02 | 03/06 | 07/11 | 12/15 | 16/20 | 21/24 | 25/29 | 30/33 | Calm | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| – | 10 | 6 | 0 | 4 | 2 | 1 | 5 | 3 | 7 | 2 | 30 |

Signed: [signature] Observer.

NOTES–1. For instructions on completion of form refer to N.Z. Met. Service Misc. Publication 107.
2. Rainfall, Maximum Temperature, Evaporation and Wind Kilometres Run, read at 9 a.m., must be entered to PREVIOUS day.

M.O. USE ONLY

Site change noted. Date: ........
Evaporimeter type code: ........

| Data Checks | Additions and Means | Computer Edit Checks | Gazette |
|---|---|---|---|
| | | | |

# APPENDIX 2

## 4.2 Grazing Behaviour Measurements in Minutes

(a) Grazing Time:

| | | | |
|---|---|---|---|
| Daytime: | Day 1 | 484 | 469 |
| | Day 2 | 444 | 476 |
| Night: | Day 1 | 180 | 79 |
| | Day 2 | 144 | 49 |

(b) Ruminating Time:

| | | | |
|---|---|---|---|
| Daytime: | Day 1 | 214 | 216 |
| | Day 2 | 259 | 229 |

(c) Standing:

| | | | |
|---|---|---|---|
| Daytime: | Day 1 | 13 | 55 |
| | Day 2 | 24 | 41 |
| Night: | Day 1 | 92 | 58 |
| | Day 2 | 69 | 63 |

(d) Lying:

| | | | |
|---|---|---|---|
| Daytime: | Day 1 | 38 | 26 |
| | Day 2 | 34 | 11 |
| Night: | Day 1 | 290 | 419 |
| | Day 2 | 356 | 461 |

(e) Sleeping:

| | | | |
|---|---|---|---|
| Daytime: | Day 1 | 11 | 0 |
| | Day 2 | 4 | 2 |

| | | | |
|---|---|---|---|
| TOTAL TIME: | minutes | 1322 | 1322 |
| | hours (approx) | 22 | 22 |