Studies of grazing behaviour by lactating cows during winter, spring and summer

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Abstract

The work outlined in this thesis was intended to study the grazing behaviour of lactating cows during winter, spring and early summer, and the effects of maize silage supplementation during winter. It also derived monthly rising plate meter equations over the period of the experiments, in order to assist with the estimation of cow intake and sward characteristics.

Supplementation influenced the quantity and relative proportions of grazing, ruminating and idling times. Total grazing times were 546 *vs.* 615-min./day, and total rumination times 403 *vs.* 333-min./day for supplemented and non-supplemented cows respectively. Substitution of pasture for maize silage occurred, with reductions in grazing time averaging 26-minutes per kg DM eaten as maize silage. Rumination values per kg of total DM eaten were similar at 29-minutes (supplemented) and 27-minutes (non-supplemented). Intake rate of pasture was not affected by offering maize silage as a supplement, but grazing time was reduced.

Cows preferred to graze during daylight hours, spending 47-57% of daylight hours grazing irrespective of daylength. Grazing activity peaked after milkings, and before dusk.

Autumn and spring calved cows were grazed together in two experiments in the spring and summer of 1998. Stage of lactation had no effect on bite rate, bite weight, and intake rate of herbage. Grazing times were related to metabolic requirements, and grazing behaviour was similar for cows which had calved in autumn or in spring.

Times for ruminating and grazing were similar for heifers and mature cows, with similar components of day and night-time grazing. Heifers have a lower intake rate (23 *vs.* 27-g DM/min), and smaller bite weights (423 *vs.* 507-mg DM/bite) without a faster bite rate (58 *vs.*56-bites/min). Heifers also ruminated for longer per kg DM eaten, with similar ruminating times to mature cows (380 *vs.* 380-min/cow/day), despite their smaller daily pasture intake (12.9 *vs.*15.3-kg DM/cow). It is suggested that the grazing behaviour of heifers is influenced by social factors, such as their dominance position in a herd.

Monthly rising plate meter equations were derived between July 1998 and February 1999. When used to rank pastures for grazing order, the importance of the slope rather than the intercept was demonstrated. However when the rising plate meter was being used to compare pasture with required target values (such as average farm pasture cover, and post-grazing herbage mass), the intercept was also important, to give an accurate pasture mass value.

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List of Abbreviations and Symbols

Abbreviations

ADF	Acid Detergent Fibre (NDF less hemicellulose i.e. cellulose and lignin)
a.m.	*ante meridiem*
ANOVA	analysis of variance
BR	bite rate
BS	bite size
BW	bite weight
CP	crude protein (Total Nitrogen × 6.25)
DM	dry matter
h	hours
ha	hectares
lwt	live weight
ME	metabolisable energy (The gross energy in the feed less that lost in faecus, urine an
MF	milk fat
min.	minute
MJ	megajoule
MJME	megajoules of metabolisable energy
MS	milksolids
NDF	Neutral Detergent Fibre (cell wall materials e.g. hemicellulose, cellulose and lignin
OM	organic matter
P	probability
PGR	pasture growth rate
p.m.	*post meridiem*
PROC	procedure
RPM	rising plate meter
SAS	Statistical Analysis System
vs.	*versus*

Weights, volumes and measures

cm	centimetre
°C	degrees centigrade
kg	kilogram
l	litre
m	meter

Statistical terms

*	significant at P<0.05
**	significant at P<0.01
***	significant at P<0.001
†	significant at P<0.1
n	number
NS	not significant
R^2	coefficient of determinaion
s.e.d	standard error of the difference
SD	standard deviation
SE	standard error of the mean

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CHAPTER 1

Introduction to present research

Introduction

The first section in this chapter covers the principles behind the grazing behaviour of ruminant animals, particularly cattle. How the animal grazes is covered in 'Characteristics of feeding', which is followed by an explanation of how a cow's day can be divided up into grazing, ruminating and idling times, in the section entitled 'time allocation'. The factors affecting herbage intake are then discussed, including the effects of pasture, bite rate, bite mass, voluntary feed intake, and rate of eating. Once the physical aspects have been covered, animal factors are discussed, including the effects of milk yield, body condition, genetic merit, age, and social factors. The effect of the environment on grazing behaviour is then considered, including issues such as the effect of daylight, and the weather.

In the second section, methods of estimating herbage mass and factors affecting this are reviewed. Estimation of herbage mass is particularly relevant to grazing behaviour, with pasture availability playing a significant role in the behaviour of grazing ruminants. A general introduction is given, then various methods of assessing pasture herbage mass are discussed. Finally, variables affecting the assessment of herbage mass such as accuracy, operator, repeatability throughout the day, season and site effects are presented.

Grazing behaviour

The importance of grazing-behaviour studies in New Zealand can be best appreciated when considered in relation to the general conditions of dairying in this country.

The almost total reliance on pasture and the great variability of the sward due to seasonal and human factors justify all the effort that can be devoted to investigations into the animals' reactions to the sward and other environmental conditions.

The behaviour of animals falls into various activity patterns including: feeding; elimination of wastes; care-seeking; care-giving; sexual behaviour; aggressive behaviour; imitation of another animal, usually of the same species; investigatory; shelter-seeking; dominance; leadership; territoriality; and social relations (O'Connell *et al.* 1987). As some patterns are more important from a commercial viewpoint they have been studied more intensively than others.

Characteristics of feeding

Dulphy *et al.* (1980) reviewed the feeding behaviour of ruminants in detail. The typical activity of a grazing animal can be described in terms of a steady forward movement with the head swinging from side to side in front of the fore legs. Cattle have to rely on the high mobility of the tongue, which is used to encircle a patch of grass and then to draw it into the mouth, where the lower teeth and the tongue are used to grip the grass bound between lower incisors and dental pad before it is broken by a head movement. After taking a series of bites, the cow manipulates the plant material into the back of the mouth using the tongue and jaw movements, chewing only two or three times before swallowing, unless the grass is short and leafy where no chewing may occur. The head is swung and steps are taken so that the next bites can be taken from a new area.

The nature of a cow's eating process is such that it is virtually impossible for the animal to graze less than one centimetre from the ground. The bite size, rate of biting, number of head swings, and rate of stepping are affected by the pasture height. Daily intake is determined by the three components of ingestive behaviour – intake per bite, biting rate, and grazing time - though it is recognised that other components of normal grazing behaviour (e.g. camping, rumination, walking, excretion) may directly affect aspects of grazing activity (Arnold 1981) and energy expenditure (O'Sullivan 1984).

Cattle in paddocks also use their previous experience in deciding how much energy to invest in attempting to graze after pasture has been grazed down to a low mass. If they know that they will be moved to a new paddock or strip each day they graze very fast at the beginning of the day, thus competing with one another for the available herbage, and do not graze much in the latter part of the period on the day's strip. Under conditions where animals are moved on after the pasture has been grazed down, they learn how to train farmers to move them at the appropriate time. The cue that they train the farmer to use is the sight and sound of a row of cows standing by the fence and bellowing.

Time allocation

Grazing animals must apportion their time each day to grazing, rumination, and to activities such as resting, drinking, walking, milking, and sleeping. Many experiments have measured the times of grazing, ruminating, and idling, although theories to explain variation in these behavioural variables are less common. The three major factors affecting time allocation are animal state (Penning *et al.* 1995), herbage quality (Penning *et al.* 1991a) and herbage availability (Penning *et al.* 1991b). In particular, animals with high energy demands reduce idling time to achieve higher daily intake (Penning *et al.* 1995). In addition, as quality of forage declines during grazing down (Hendricksen and Minson 1980), longer processing (rumination) time is required per gram ingested. Sheep and cattle also increase grazing time as herbage availability declines in an effort to meet their intake requirements (Allden and Whittaker 1970). For grazing animals, availability of herbage is usually the factor limiting intake.

As a rule dairy cows in New Zealand divide their day into two periods of distinct activities: (a) the daylight period, when grazing is the main activity and (b) the hours of darkness, when the main activity is rumination. Grazing activity follows a distinct pattern in that long periods of continuous grazing are followed by shorter periods of idling, rumination, and even of total rest. There are two major peaks of feeding, one each after morning and afternoon milking, and a smaller peak of grazing about midnight (O'Connell *et al.* 1987) if feed is available. The existence of a large evening grazing bout (meal) has been reported for dairy cows (Rook *et al.* 1994) and for sheep (Penning *et al.* 1991b) who speculated as to its causes. Rook and Huckle (1996) suggested that this meal may be considered as a core grazing period and that any required changes in grazing time are made preferentially at other times of the day. However, in total, three or four periods of grazing occur between the morning and afternoon milkings and one or two immediately following the afternoon milking, in addition to a short period in the middle of the night (Hancock 1950b). A grazing period may occur if morning milking is delayed beyond daybreak and pasture is still available. A period of rumination occurs around midday although some cows showing a typical grazing pattern have been observed to delay rumination until the afternoon milkings, indicating that the cyclic pattern of grazing is not caused by the need to ruminate at intervals.

Grazing time

When herbage availability is extremely low, it is common to observe a sharp decline in grazing time (Hodgson 1985) or biting rate (Allden and Whittaker 1970), and animals become restless, graze intermittently, and are very selective. Allden and Whittaker (1970) suggested that, because intensive rotational grazing management conditioned the animals, this behaviour was due to animals anticipating new feed.

Conversely, animals grazing at high allowance may reduce grazing time if their energy requirements are satisfied (Penning *et al.* 1991b). However, grazing on grass pasture is an energy intensive activity, with small marginal rates of energy gain, (Woodward 1997), so satiety may not often be observed in practice.

When pasture is of moderate to high quality, the time spent searching for pasture is typically small (estimated at 0.4-seconds per bite for sheep by Parsons *et al.* (1994)), and tends to occur concurrently with mastication of earlier bites, so that it is reasonable to assume that time devoted solely to searching is effectively zero (Spalinger and Hobbs 1992). When pasture consists of patches of both high and low quality, on the other hand, the time spent searching for acceptable patches becomes important, and patch selection models are required (Stephens and Krebs 1986). Patterson *et al.* (1998) suggested that the decline in intake rate during grazing reflects changes in the balance of activities i.e. an increased proportion of time spent in movement and forage selection rather than changes in biting rate during each grazing bout.

Grazing studies have shown that cows normally spend 8 to 10-hours a day to satisfy their appetites. However, this varies due to many factors such as weather, pasture quantity (length) and quality, the nutritional needs of the cow, oestrus, pregnancy and health. With dry tropical pastures as reported by Stobbs (1974) in Queensland, Jerseys grazed for 9 to 12-hours/day. It was considered that 12-hours was the upper limit of grazing time and only under extreme pasture shortage had grazing times in excess of 13-hours been recorded. This upper limit finding agrees with Hodgson (1986), of about 750-minutes, with bites per minute ranging from 20 to 90. This is reduced when the animal has to graze selectively, or if the bite size is reduced because the sward is thin or stemmy.

In grazing lactating dairy cows, two main grazing bouts are normally observed: one in the morning and one in the evening. This pattern of grazing may be due to a short-term fasting effect during milking (Rook *et al.* 1994). Grazing time and meal duration increase significantly from spring as the grazing season progresses, while the number of bouts of all activities decline (Rook and Huckle 1996). Stockdale and King (1983) found grazing time in mid-summer increased as pasture allowance decreased to about 32-kg DM/cow/day, but as pasture allowance decreased further, grazing time also decreased. A pasture allowance of 32-kg DM/cow/day corresponded to a stocking rate of about 5.5 cows/ha. Rumination time increased by 0.03-h for each kg increase in pasture allowance, while resting time was not affected by treatment. The experiment was characterised by major periods of grazing during the day until sunset, with rumination and resting mainly occurring at night. Virtually no grazing occurred between 21.00-hours and milking time the next morning. On average, the cows spent 40% of their time grazing (9.6-h), 27% ruminating (6.5-h), 23% resting (5.5-h), and 10% at the dairy.

Rumination

Ruminants tend to ingest feed rapidly and to ruminate it later. Rumination allows cattle to regurgitate, masticate, and then swallow food that they have previously ingested into the rumen. Thus animals can continue their digestive activities at leisure, when away from a preferred grazing area or while sheltering during bad weather. O'Connell *et al.* (1987) found a high correlation between rumination and lying down behaviour. However, rumination can and does occur while animals are either standing quietly or walking slowly, especially when taken to and from the milking shed (Hancock 1950a), while being milked, or in bad weather e.g. heavy rain. If cows are disturbed during periods of rumination they may stop ruminating and after a period of idling revert to grazing. Thus it appears that the physiological urge to ruminate is not always compelling. Another interesting observation is that the change from ruminating to grazing is often abrupt whilst that from grazing to ruminating is not. Thus cows often begin grazing while masticating the last bolus, but a cow will invariably allow some time to elapse after grazing before starting to ruminate (Hancock 1950a).

Time spent ruminating amounts, on average, to three-quarters of the time spent grazing. The herbage intake rate and the total time spent eating affect the distribution of time between eating or grazing, subsequent rumination, and other activities in the day of a ruminant (Figure 1-1). Day length and season also affect the diurnal pattern. During the 24-h cycle, about 15 to 20 periods of rumination occur, but the duration of each period may differ vastly; it may last only a few minutes or it may continue up to one hour or even more at one stretch. The hours of darkness are mainly occupied by alternating periods of rumination and total rest, with the peak period for rumination being shortly after nightfall, after which it declines steadily until shortly before dawn when grazing begins. The decline in the ruminating activity is associated with shortening periods of rumination. The enforced period of loafing at morning milking is largely occupied by ruminating, but if milking is delayed and the cows left on the pasture, they will graze instead.

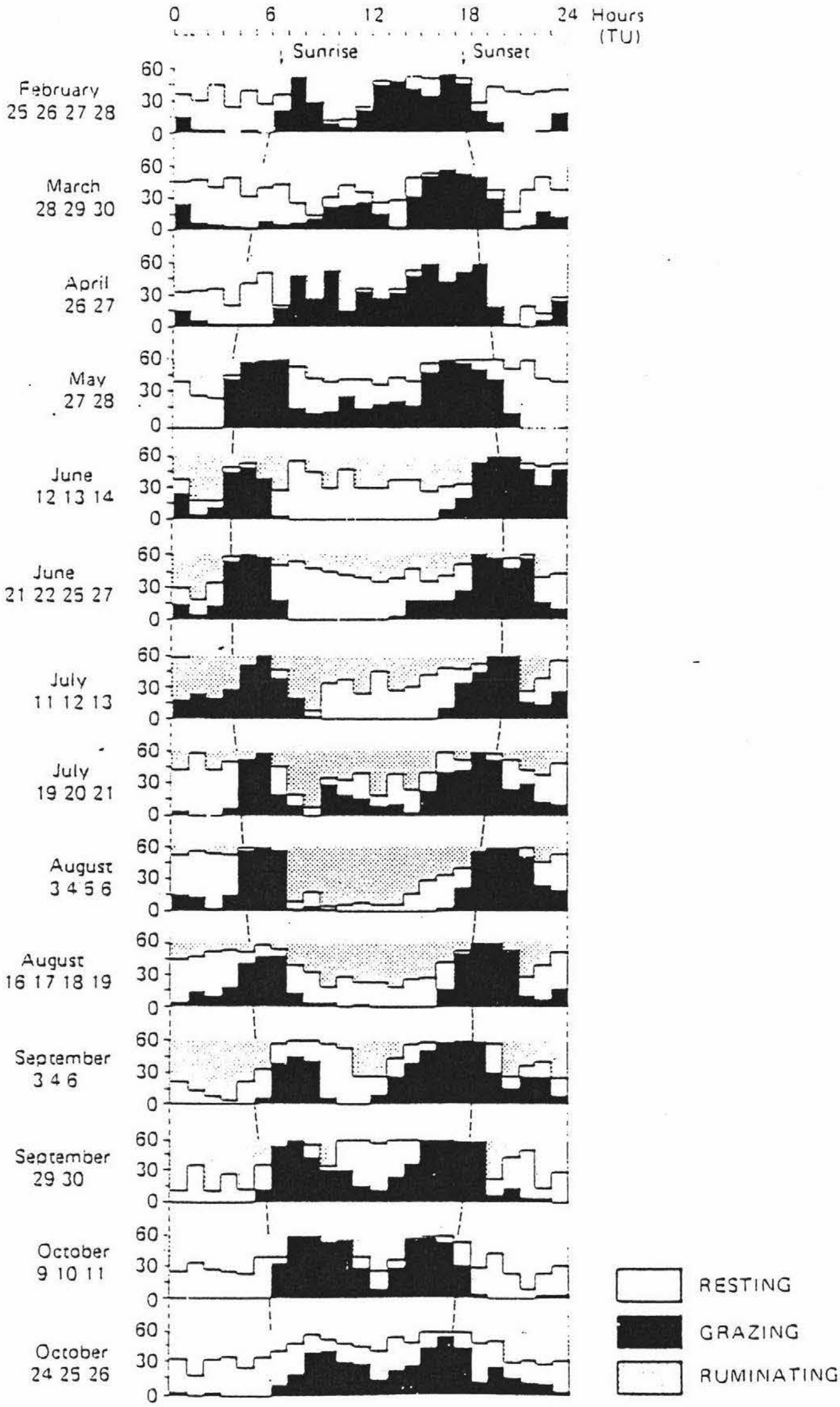

Figure 1-1 Circadian pattern of activities in grazing sheep (Arnold and Dudzinski 1978). White areas indicate resting; black areas, grazing; and striped areas, ruminating.

Rumination time is assumed proportional to the quantity and quality of their food intake (Woodward 1997). Since every particle of food ingested by a ruminant must be reduced to a size that can leave the rumen, this is a reasonable simplification, which is supported by the data of Penning *et al.* (1991b) for sheep grazing in springtime, which provided a linear relationship between daily intake and rumination time. Woodward (1997) reanalysed the data of Penning *et al.* (1995), and reported average rumination times of 0.16-min/g for grass and 0.094-min/g for clover. Lactating sheep spent less time ruminating per gram ingested than dry sheep, suggesting that rumination time is dependent on animal state, although there was also a difference in absolute dry matter intake. Heifers spend longer ruminating/kg herbage DM than cows, possibly because of reduced rumen capacity, and autumn-calvers tended to spend longer ruminating/kg DM intake than spring-calvers (Phillips and Leaver 1986a).

Idling

Idling time is usually viewed as merely the surplus left over after an animal has completed grazing and ruminating. In contrast, Woodward (1997) thought of this as a requirement that limits the sum of grazing and ruminating time within a day. He proposed that a certain resting time is essential to animal well being, partly due to activities that have fixed daily time costs, e.g. milking. Idling time was therefore assumed a fixed cost for a given animal, independent of pasture availability. This assumption is supported by the data of Rook *et al.* (1994) who observed that the idling times of cows were similar (around 460-min./d) across a range of pasture and supplement treatments. This increased grazing time occurred at the expense of a decrease in rumination time rather than in idling time.

Idling times may however differ between animal classes e.g. (Newman *et al.* 1994). The data of Penning *et al.* (1991a, 1991b, 1995) suggests that the idling times of lactating ewes are less than those of dry ewes (446-min./d compared to 553-min./d). In general, animals with low energy requirements would be expected to have high idling times, whereas animals with high demands (e.g. lactating) may be able to reduce idling time to some extent to achieve higher energy intake. Other variables, in particular prehension and rumination times, may also vary with animal type and state (Woodward 1997).

The assumption that idling time is constant also requires that animals be not fed to satiety. Penning *et al.* (1991a) observed higher idling times by sheep grazing clover monocultures compared with those grazing grass. Their explanation was that sheep were quickly satiated when grazing pure clover, and so did not need to continue grazing. It is difficult for animals grazing on grass-dominant pasture to achieve high intake rates, and hence satiation within a grazing day. This is because bite weights are lower than on clover, hence more time (and energy) must be spent grazing. In addition because of the lower nutritional value of the herbage, more ruminating time per unit of energy intake is required (Woodward 1997).

Herbage Intake

The herbage intake of grazing animals can be considered in terms of the balance between the effects of metabolic, physical, and behavioural controls, all of which may be influenced by a range of plant and animal variables. In addition, it has been suggested that these factors may be influenced by the hunger-satiety status of the animal (Baile and McLaughlin 1987, Patterson *et al.* 1998).

Daily herbage intake in grazing cattle is determined principally by grazing time (Spedding *et al.* 1966), biting rate (Allden and Whittaker 1970) and dry-matter (DM) intake per bite (Hodgson 1986, Greenwood and Demment 1988), which in itself is a function of bite volume and herbage bulk density (Laca *et al.* 1992). A schematic description of the major components of plant characteristics, bite size, searching and handling and how these contribute to prehension bite rate and intake rate is shown in (Figure 1-2). In cattle, grazing behaviour may also relate to live weight, sex, physiological condition, and production level of the animal.

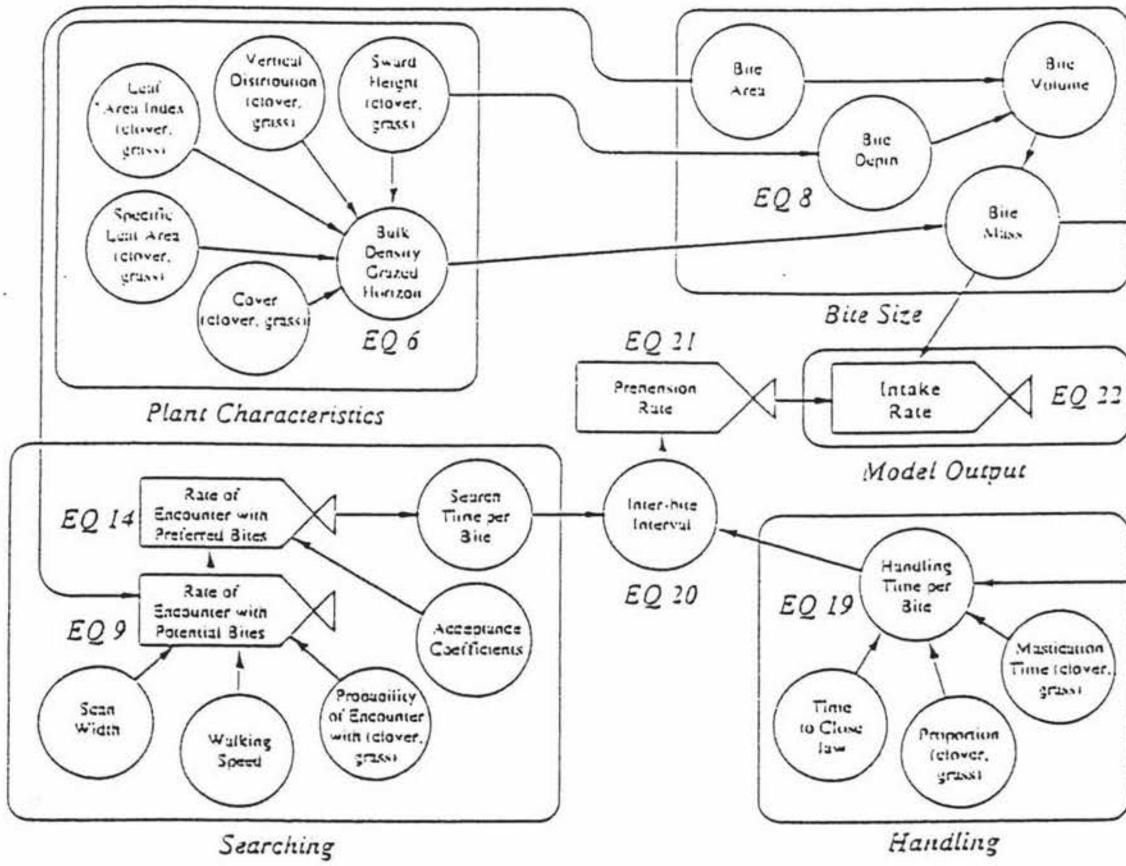

Figure 1-2 A schematic description of the model described by Parson *et. al.* (1994) showing the major components of plant characteristics, bite size, searching and handling and how these contribute to prehension bite rate and intake rate. The diagram refers to the major equations of the model that describe these inter-relationships.

Pasture effects

The influence of the total amount of pasture available to each cow (kg DM per cow per day) on grazing behaviour will vary according to the length and density of the grass. It is therefore important to consider the amount of grass available per hectare as well as per cow.

The grass offered to animals varies in quality due to seasonal factors, from young, highly digestible grass with high energy content (megajoules (MJ) of metabolisable energy (ME) (MJ ME)), and crude protein (CP) that generally contains little fibre, to mature, poorly digestible fibrous material. As each combination of quantity and quality modifies grazing behaviour in a particular way, it is evident that the type of pasture given to the animals is a factor of great importance amongst those that determine the grazing animals' reaction to their environment.

Quantitatively poor pastures (low mass, short height or low allowance per cow) result in long grazing, low intakes, and low ruminating times. The ratio of ruminating to grazing time is generally very low, with the lowest being reached when the quality of the grass is high due to the low fibre content, and the high digestibility of the pasture.

Other factors being equal, herbage intake increases with increasing height or density of the sward because the amount taken per bite is increased (Figure 1-3). Therefore cows work longer hours under adverse grazing conditions, as the times spent in grazing, ruminating, or both, are longer than when the pasture quantity and quality are optimal.

Garcia, J (1998) conducted two short-term grazing behaviour experiments with high genetic merit Holstein-Friesian dairy cows, EXP1 (September) and EXP2 (December) finding 74% (13-hours daylight) and 68% (15-hours daylight) respectively of grazing occurring during daylight hours. Hancock (1950a) intensively studied the grazing behaviour of cows in the 1940's, and reported that for cows which are grazing high quality pasture in the same enclosure during the day and night, the day/night-grazing ratio averaged 60:40. However if the pasture was quantitatively poor the ratio became 75:25, possibly because the cows were too tired to graze during the night, or because they were aware that no more edible sward was left. No indication of herbage height, mass, or allowance was given to be able to define what precisely quantitatively poor pasture was considered to be.

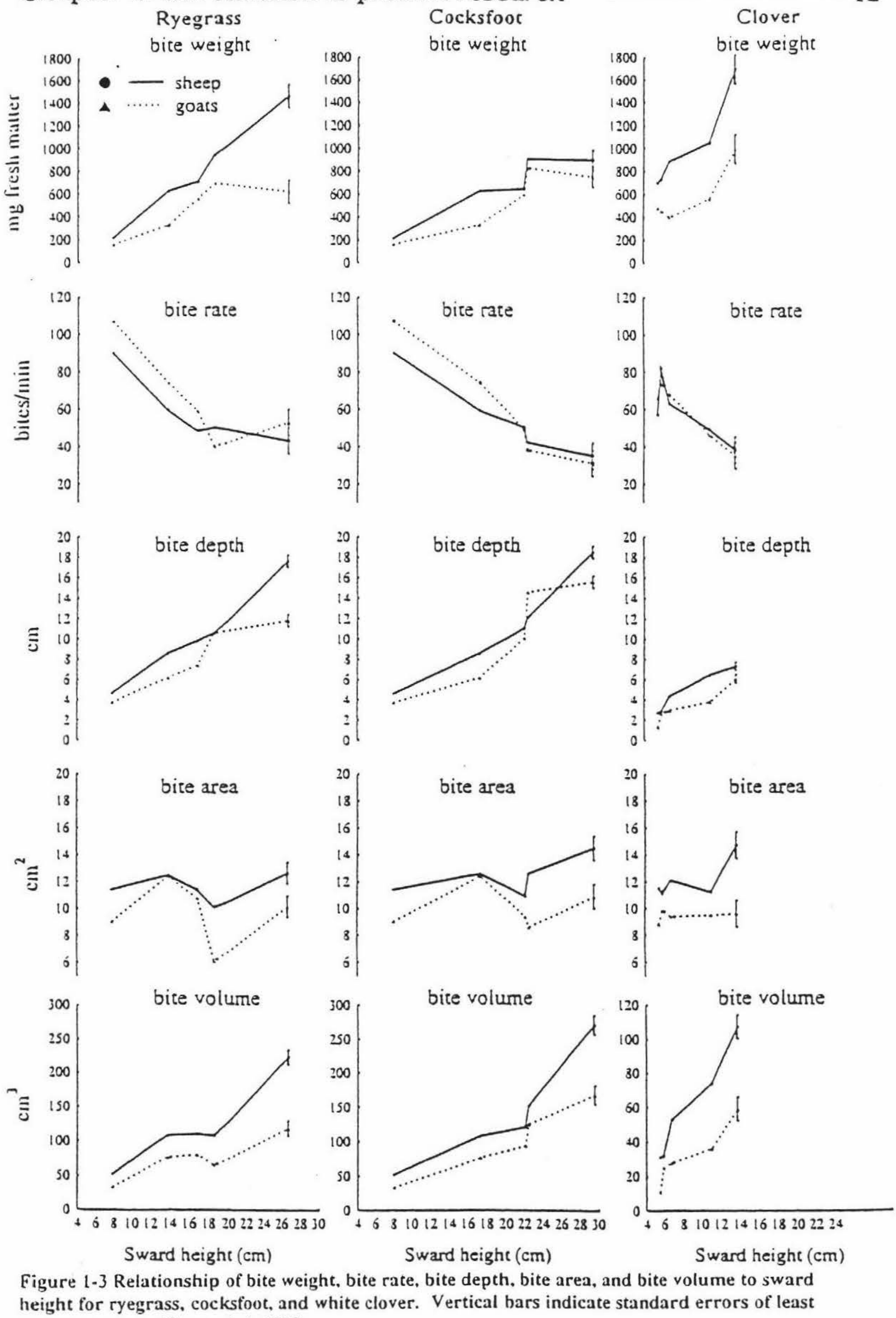

Figure 1-3 Relationship of bite weight, bite rate, bite depth, bite area, and bite volume to sward height for ryegrass, cocksfoot, and white clover. Vertical bars indicate standard errors of least squares means. (Gong *et al.* 1996)

Bite Rate

Ungar and Noy-Meir's (1988) model states that, if the prehension, mastication times and bite weight (BW) are respectively t_p (min./bite) and t_m (min./g), BW (g) then rate of biting (BR, bites/min.) is:

$$\mathrm{BR} = \frac{1}{t_p + t_m \,\mathrm{BW}} \qquad [1]$$

The rate of grazing (bites/min.) is on an average similar during day and night (Hancock 1950b). However, great variations occur throughout the 24 hours, in that the rate is generally highest in the beginning of a grazing cycle followed by a continuous steep decrease towards the end. Bite rate usually tends to decline as sward height or herbage mass increase, and as intake per bite increases, principally because the ratio of manipulative to biting jaw movements increases as intake per bite and the size of individual plant components prehended increase (Chambers *et al.* 1981) (Figure 1-3). Attempts by cows to maintain herbage DM intake by increasing bite rate and grazing time, seem to be limited by a ceiling of approximately 66-bites/min and 10-h/day, respectively (Phillips and Leaver 1986a). Individual cows, however, recorded values as high as 91-bites/min. and 12.8-h/day during periods of low herbage availability (Phillips and Leaver 1986a). The data of Allden and Whittaker (1970) and Penning *et al.* (1991b, 1995) show that the bite rate (BR) declines when very small bite weights are being achieved. The same behaviour was observed by Jamieson and Hodgson (1979a) with strip-grazed calves, while continuously grazed calves in a similar experiment (Jamieson and Hodgson 1979b) did not exhibit this behaviour. Jamieson and Hodgson (1979a) suggested than animals under strip-grazing anticipate new fed and so are not motivated to extend grazing hours.

A decline in bite rate as the grazing session progressed has been observed in grazing experiments (Chacon *et al.* 1976, Jamieson and Hodgson 1979a, Dougherty *et al.* 1987, Dougherty *et al.* 1989, Chilibroste *et al.* 1997), but not invariably (Forbes and Hodgson 1985).

High yielding cows tend to graze at a higher biting rate than low yielders (Bao *et al.* 1992). Biting rate is highly negatively correlated with the cumulative time spent grazing during a grazing bout (Bao *et al.* 1992). This trend is likely to be related to physiological status (such as a strong desire for food at the start of grazing and the gradual filling of the rumen as grazing progress which determines the animal's grazing intensity) than to sward conditions. However the actual biting rate is also influenced by sward status (Bao *et al.* 1992, Chacon *et al.* 1976).

Bite rate is significantly influenced by fasting duration and an increase in BR appears to be the primary method by which grazing cows are able to increase DM intake rates to compensate for increasing degrees of hunger (Patterson *et al.* 1998). In addition Patterson *et al.* (1998) found fasting had a significant effect of bite mass, with DM intake per bite following 6 and 13-hour fasts being proportionately about 0.25 greater than that calculated following 1 and 3-hour fasts. It was suggested that the changes in bite mass are due to an increased use of the tongue to 'sweep' larger areas of tall herbage into the mouth prior to biting and reflect differences in the hunger drive.

Bite Mass

Bite mass is a fundamental determinant of intake rate per hour or day and it depends on sward structure (Arias *et al.* 1990, Ungar *et al.* 1991, Dougherty *et al.* 1992, Laca *et al.* 1992, Laca *et al.* 1994b, Flores *et al.* 1993). Bite area increases with sward height but decreases slightly as sward bulk density increases (Woodward 1998). Stobbs (1973) studied grazing behaviour in tropical Australian conditions and concluded that increasing sward bulk density, low stem content and a high leaf/height ratio all tended to increase bite size. Bite size is therefore optimal on tall, dense, uniform, easily eaten swards.

Animal state is reflected indirectly through bite weight, since animals with higher energy demands are less selective, take larger bites (Newman *et al.* 1994), masticate less, and graze for longer periods (Penning *et al.* 1995). Social factors such as group size also have an effect (Penning *et al.* 1993). Animals in energy deficit obtain larger bite weights, probably by increasing bite area, in order to increase intake rate (Newman *et al.* 1994).

Field studies of grazing ruminants have generally found an increase in bite rate with decreasing bite mass (Hodgson 1985, Forbes 1988), however Chilibroste *et al.* (1997) found no indication of a close relationship between the two variables. Although Laca *et al.* (1994b) observed that depletion of the grazing patch affected bite mass but not bite rate, they are not independent, the most obvious functional link being that fact that larger bites would require more ingestive mastication. Nevertheless, this relationship may not be linear, as Laca *et al.* (1994a) observed that the cattle were able to chew and bite with the same jaw movement. This indicates the existence of a critical bite mass below which time per bite and total number of chewing movements does not change.

Voluntary feed intake

Voluntary food intake is the weight eaten by an animal or group of animals during a given period of time during which they have free access to food.

One of the major factors determining energy intake and indeed one of the primary determinants of high producing dairy cattle is a cow's ability or drive to eat. This capacity is influenced by many factors that are worthy of consideration due to their effect on production.

Voluntary DM intake of the first meal (Gill and Romney 1994) and for the whole 24-hour day (Forbes 1995, Dulphy and Demarquilly 1994, Van Soest 1994) is believed to be controlled by metabolic (Mayne and Wright 1988) and physical restrictions (Waldo 1986), and/or environmental limitations (Forbes 1995). It is often lower than the potential intake (the weight of food required to fulfil all of the animal's nutrient requirements). There is also a positive relationship between digestibility of herbage dry matter and level of voluntary intake. Under grazing conditions, ingestive behavioural limitations may also restrict the voluntary DM intake (Hodgson 1985, Forbes 1988). It seems probable that a combination of signals rather than one single signal controls the initiation and termination of a meal (Mbanya *et al.* 1993, Forbes 1995).

Body size is a major determinant of voluntary feed intake (VFI). Weight per se is not a consistent determinant of intake due to variations in frame and fatness. Extreme fatness can depress VFI by up to 25% and there is some evidence that there is depression of intake in very thin cows (Lean 1987). Intake is also influenced by rumen size and factors affecting rumen fill (i.e. distension and rumen flow rates) especially with forage based diets.

Rate of Eating

A high level of feeding activity is usually observed after fresh food is offered. Prior to periods of high intake, selectivity of pasture and food plants increases, becoming very marked during phases of high intake. After such a phase, grazing becomes intermittent again and the level of selectivity decreases. Suzuki *et al.* (1969) found that the mean rate of eating of DM by lactating cows was greater for silage, at around 6-kg/hr, compared with hay (2.4-kg/hr). The figure for silage is higher than that observed by other authors and this is probably accounted for by the fact that Suzuki's cows were not fed *ad libitum* and were therefore eating after a period without food. Jackson *et al.* (1991) reported a mean rate at which lactating mature cows ate grass silage of 3 to 3.4-kg DM/hr.

Presumably in systems where food is limited, e.g. dairy cows fed concentrates in a group, the fastest eaters will consume more and produce more milk, thus rendering themselves more likely to be selected as the mothers of future cows, i.e. selection for fast rate of eating. However, the rate of eating by cows low in the dominance order was found by Kenwright and Forbes (1993) to be significantly faster during the 40-min peak periods after each milking (300-g fresh matter/min) than at a quiet period (10.00 to 12.00-h) (200 g/ min.) and the time spent eating was significantly shorter (14.6 *vs.* 18.7-min.). The most dominant animals did not eat significantly faster during these peak times than at other times of day (270 *vs.* 250-g/min.) but spent a little more time eating than at other times of day (19.9 *vs.* 17.6-min.). Thus, the dominant cows did not feel under pressure to eat quickly at busy times, as they were confident of being able to recommence eating when they became hungry (Kenwright and Forbes 1993).

Animal effects

Milk yield

The rapid increase in energy requirements during the first few weeks of lactation is not usually matched by such a rapid rise in voluntary intake and this lag is longer with forages (Owen *et al.* 1968), and with heifers than with cows (Dulphy and Faverdin 1987). Bines (1979) summarised the results of 20 experiments, which recorded changes in feed intake in early lactation. In cows given diets of constant composition milk yield peaks 5 to 7-weeks post partum while maximum intake is reached between 8 and 22-weeks after calving, and the increase in intake from week one post partum to time of peak intake varied between 2 and 111% (Bines 1979). The mean depression in intake in the first week of lactation was 33% and the mean week of peak of maximum intake was week 14.4. The poor relationship between daily milk yield and intake, caused by the lag in intake in early lactation, indicates that other factors than live weight and milk yield may need to be included in the prediction of DMI (Ingvartsen 1994).

The generally low correlation between animal performance traits and grazing behaviour may indicate that the long-term nutritional demands of the animal are relatively unimportant in determining short-term foraging behaviour (Rook and Huckle 1996). Rook and Huckle (1996), Phillips and Hecheimi (1989), and Phillips and Leaver (1986b) found no significant relationships between milk yield and grazing time, suggesting that high yielders were not required to graze for much longer than low yielders do.

Body condition

Intake capacity of ruminants is influenced by their body condition or fatness (Forbes 1986). It has been shown that lean non-lactating cows eat around 24% more feed than fat cows (Bines *et al.* 1969, Bines and Morant 1983). Cows fed at maintenance level during the dry period ate 11% more during the first 16 weeks of lactation than those fed at 1.8 of maintenance (Lodge *et al.* 1975). In other words, cows which are fat at calving tend to increase intake in early lactation at a lower rate than thinner cows (Garnsworthy and Topps 1982, Kunz *et al.* 1985, Treacher *et al.* 1986, Mayne and Wright 1988, Holter *et al.* 1990).

Neilson *et al.*(1983) found that silage intake varied inversely with body condition in groups of Friesian cows. Cows that were fatter at calving lost weight but milk yield was not affected. Land and Leaver (1980) observed that fatter cows ate less but gave more milk than thinner ones.

Further work is needed to determine how intake capacity in cows depends on body condition, and especially how intake capacity in early lactation depends on previous feeding in late lactation and the dry period, and consequently, on body condition at calving (Ingvartsen 1994).

Genetic Merit

High merit cows spend slightly but significantly longer grazing over the entire observation period, and have a longer first grazing bout than low merit cows (Bao *et al.* 1992, Brumby 1959). The small magnitude of the difference in grazing time might suggests there might be a difference in grazing efficiency or metabolic efficiency between high and low merit cows. The faster biting rate found in high merit individuals might also be a contributory factor.

Age

The intake capacity in the first part of lactation of primiparous cows calving at an age of 2-years and weighing approximately 500-kg is only around 80% of that of multiparous cows, and only about two thirds of this difference can be explained by differences in live weight and milk yield (Jarrige 1986).

A cow's age has a greater effect on grazing behaviour than on milk yield. In addition Bao *et al.* (1992) found a significant negative relationship between both total grazing time and length of first grazing bout and lactation number, where younger cows tended to graze for longer than older ones.

Social factors

The main food-producing farm animals are species that live in social groups. If cattle, sheep or pigs are taken from their group and housed individually they eat less (Kidwell *et al.* 1954). This could be a response to lack of companions in general or to lack of companions at feeding time. Even when food is continually available, groups of farm animals usually synchronise their feeding within the group. Behaviour studies, such as those of Hancock (1950a), show that cows act in unison in their grazing patterns, Hancock showed that two herds maintained their own unique grazing cycles, even when only separated by a single electric wire. He postulated that each herd operated under its own set of herd laws. As a consequence of such effects, the duration (Hodgson and Wilkinson 1967) and behaviour (Rook and Huckle 1995) of grazing is much more constant when animals graze in a herd than would be expected when they graze individually. The residual coefficients of variation reported by Rook and Huckle (1996) compared to variations between animals and between periods indicate that, although there was little overall difference between animals, they did react differently to the conditions in different periods.

Kenwright and Forbes (1993) observed a clear triphasic pattern of eating by cows milked three times per day, with peaks of feeding activity occurring during the periods after return from milking. These peak periods included large meals, suggesting that some cows were monopolising the feeders thereby preventing others from eating at this time. The 01.00-06.00 h period was relatively quiet with 13% of the total number of meals taken in the 15% of the total time spent eating. The more dominant animals ate less at night (01.00-06.00 h) than those at the bottom of the order. Therefore heifers low in the social dominance order were not able to satisfy fully their desire to eat when the level of competition for feeding space was high. The fact that lower yielders were lower in the dominance order (calculated according to Rutter *et al.* (1987) than high yielders, but ate more at night suggests that high demand for nutrients was not the prime cause of nocturnal eating, although it is possible that low dominance caused low intake which resulted in lower milk yield. It is more likely that those lower in the dominance order were prevented from meeting their needs during the day and were thus forced to satisfy their requirements by eating in the middle of the night. When they did manage to eat at the most popular times of day it was in short meals, eaten at a rapid speed and presumably terminated by the arrival of a more dominant animal. Stakelum *et al.* (1987) found no relationship between herbage intake or any ingestive or grazing behaviour activities and dominance values. Age and weight were best correlated with dominance value, and dominance value had a relationship to daily milk yield. They concluded that under the grazing system used, with 1400-m^2 allocated daily per cow, social interactions between cows is unlikely to inhibit or restrict their herbage intake or grazing behaviour.

Environmental Factors affecting grazing behaviour

Environmental factors (ambient temperature, humidity, solar radiation and wind speed), animal factors (level of production, breed, coat colour, stage of lactation and health status) and thermoregulatory mechanisms (vasodilation, vasoconstriction, sweating and respiratory rates) impact on the energy exchange between the cow and the environment which affects body temperature and animal behaviour (Bennett *et al.* 1985, Shearer and Beede 1990a, Blackshaw and Blackshaw 1994).

Circadian Rhythms

The time at which cattle and sheep start and stop the major morning and evening grazing periods is influenced by the times of sunrise and sunset, with management methods and social factors also affecting this (Fraser and Broom 1990). Depending on the size of the herd up to 3.5-hours/day may be spent around the milking facility, and milking may be carried out at times which otherwise would have been used for peak grazing (Figure 1-4). Dairy cows may be forced to increase their night-time grazing period from about 1 up to 4-hours to compensate for decreased daytime grazing. This is especially the case when nutritional demands are high, such as after calving.

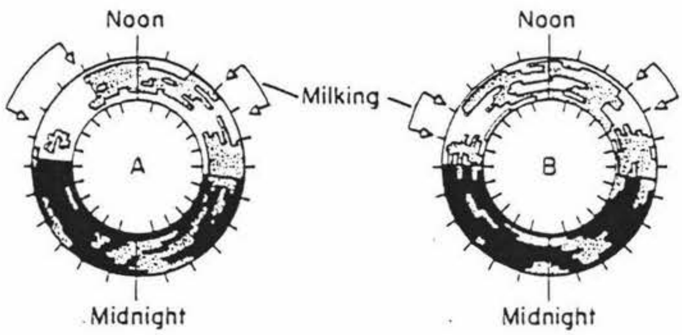

Figure 1-4 Typical weekly grazing patterns for a cow recorded by a grazing clock. A, second week of lactation; B, peak lactation when 4 weeks in milk. Grazing time = hatched; day = white background; night = black background (Kilgour and Dalton 1984).

The ratio of day to night grazing is affected by very hot weather in the middle of the day in summer when more night grazing occurs, especially if the moon is bright (Dulphy *et al.* 1980) (Figure 1-5). Kerr *et al.* (1987) studied the behaviour of cows in Queensland over a number of years. Cows were less inclined to graze on hot days. They did not graze at all when the temperature exceeded 35°C, which explains why cows graze longer at night during the hot summer months. When daytime maximum temperatures were 20°C, about 60% of all grazing was done between morning and afternoon milkings. While the maximum temperatures were 28°C, about 35% of the grazing was done during this time, and at maximum daily temperatures of 30C, less than 25% of all grazing could be expected during this time. Cows grazed for a shorter time as the maximum daily temperature increased.

Cold and wet spells of weather in winter can reduce grazing, but they do not have a very significant effect upon the ratio of day to night grazing (Fraser and Broom 1990). The recorded range of grazing times is similar for sheep and cattle (4.5 to 14.5-h) (Arnold and Dudzinski 1978), with the distribution shown in Figure 1-6.

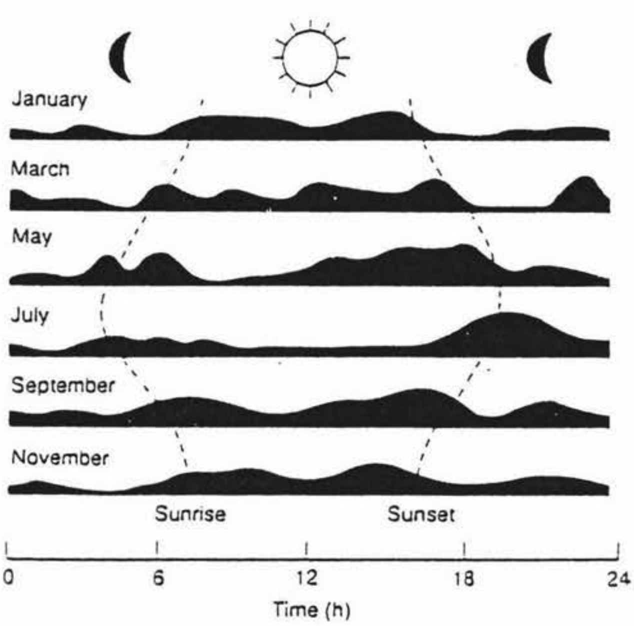

Figure 1-5 Diurnal feeding patterns of grazing cattle at different times of year (Dulphy *et al.* 1980)

The reduction in day length in the autumn caused a compression of grazing time by dairy cattle set-stocked on pasture to mainly within daylight hours, and an increase in ruminating time at night (Phillips and Leaver 1986a). Rook and Huckle (1996) found a strong correlation between grazing time, number of bouts of all activities and meal duration and day of the year, which is probably explained by the similar correlation with day length. Cows exhibit a clear nycterohemeral pattern in grazing behaviour e.g. (Rook *et al.* 1994). It has been shown that nycterohemeral patterns in grazing behaviour of sheep change as the season progresses (Penning *et al.* 1991b), with more grazing occurring during darkness as day length declines. This change in grazing behaviour may be an evolutionary adaptation to the seasonal availability of food under natural conditions. It has been shown in indoor studies with dairy cows that both intake (Kay 1979) and metabolic rate (Blaxter and Boyne 1982) decline with decreasing photoperiod, however there have been no reported findings of this in grazing animals.

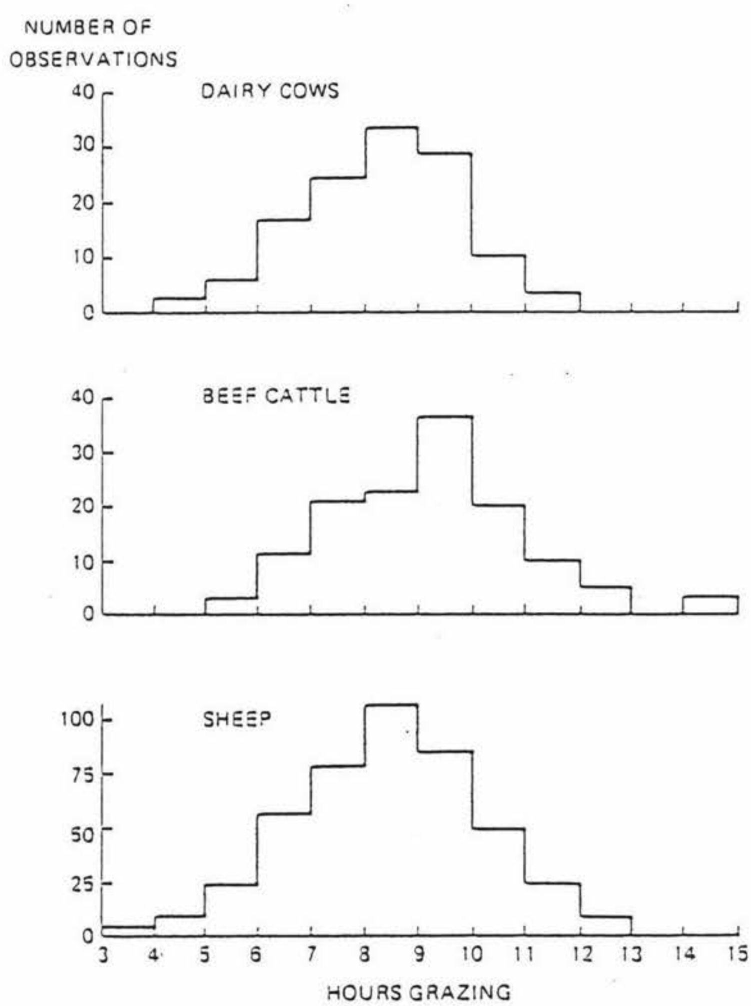

Figure 1-6 Distribution of times spent grazing by dairy and beef cattle and sheep (Arnold and Dudzinski 1978)

In New Zealand 50-years ago, animal behaviour research with identical twins was initiated and conducted by Hancock (1950a, 1954). This classical, detailed work on grazing behaviour is summarised in Figure 1-7 (seven 24-h periods throughout one season between November and May), with cows producing an average of 0.46-kg milkfat (MF) per day, grazing for 411-minutes. The feed requirements for this level of milk production can be estimated at 11 to 12-kg DM/cow/day. Therefore dividing estimated intake by the total number of recorded bites, bite size was approximately 0.46-g/bite. Extrapolating from this, if the cows had produced 1-kg MF/day, as would be expected with modern production levels, Hancock's cows would have required 15-kg DM/day or 35,700 bites (assuming bite size stays constant), with a grazing time of approximately 700-minutes. Of the 411-minutes grazing time per 24-hours reported by Hancock, slightly less than

60% of the total grazing time took place between 0700 and 1500-h, and slightly more than 40% between 1700 and 0445-h. This ratio was constant under all weather and pasture conditions. On average, almost 85% of the total grazing time was spent during daylight and only 15% during darkness. Even under ideal grazing conditions, dairy cows did not spend much more than half of the time between morning and afternoon milkings in actual grazing. The rest of the time was used for searching for food, resting, and for rumination. Of the period following the afternoon milking (1700 to 0445-h), only approximately 25% was occupied with grazing.

Considering the distribution of all grazing, ruminating and resting activities together, the habits of dairy cows in NZ are essentially diurnal, as best illustrated by the ratio of grazing to loafing (time spent standing or walking, not grazing) to lying down, which was approximately 5:2:2 during daylight compared with 1:1:8 during darkness (Hancock 1954). Herds show three main periods of lying down: (a) before evening milking; (b) between sunset and midnight; (c) between the active period around midnight and daybreak. At peak periods of lying down, over 90% of the cows may be lying down in sheltered positions (O'Connell *et al.* 1987).

Grazing time, min	411
Loafing time,[1] min	195
Lying down time, min	580
Distance covered, m	2778
Defecations, no.	12.2
Urinations, no.	10.1
Water, drinks	3.7
Total bites grazing, no.	23,966
Bites, min	51.3
Rumination time, min	324
Total chews (rumination), no.	17,117
Rumination: grazing	.75[2]

[1]Time spent standing or walking, not grazing.

[2]Ratio of ruminating to grazing time was .95 in steers and .46 in sheep grazing the same pasture (66).

Figure 1-7 Behavioural patterns for monozygotic cattle twins on pasture (Hancock 1954,Hancock 1950a).

Weather

Behaviour is not significantly correlated with meteorological conditions and there are no significant correlations between production traits and mean behaviour of cows across periods (Rook and Huckle 1996). Rook and Huckle (1996) found low correlations with meteorological variables in a temperate environment, indicating that the immediate external environment had little effect on behaviour over the range of conditions examined in the experiment.

RAIN

Grazing by sheep in a particular hour of the day is reduced when there is rainfall in that hour but increased grazing later compensates for this. Rainfall also reduces the time spent ruminating (Champion *et al.* 1994). Ruckebusch and Bueno (1978) observed the mean values of both walking and loafing times remained similar whatever the weather, the major feature being longer periods of resting for fine weather, which may be important for energy requirements. In addition, the major periods of grazing occurring at sunrise and sunset were not clearly delineated during wet weather. In this case, the animals seemed likely to avoid long periods of inactivity during the daytime and even during night-time. Cloud has the effect of shortening the day, but rain has little effect unless it is particularly heavy and accompanied by wind. In the latter circumstances cattle and sheep will change their direction of grazing to move with the wind.

TEMPERATURE

Sheep can probably sense how hot a day it is going to be, and so too can cattle. Low *et al.* (1981) working in Central Australia found that the time at which cattle started grazing in the morning correlated with the subsequent maximum temperature, and actual temperature influences the time at which morning grazing time ceases. An analysis of all available data by Arnold (1985) where climatic conditions have been recorded indicates that when daily maximum temperatures are <15°C, little night-time grazing is done by cattle. But when the daily maximum temperatures are high, >25°C, night grazing varies from 0 to 70% of total grazing time. This variation may well be influenced by differences in humidity as well. Much greater variability of night-time grazing was reported by Phillips and Denne, (1988) although they found more variability in the evening than in the morning in contrast to Rook and Huckle (1996). On the other hand, Gary *et al* (1970) and Prescott *et al* (1994) reported little effect of temperature on the grazing behaviour of cattle even under more extreme conditions.

Production losses start occurring when animals are exposed to conditions either above or below their thermal neutral zone (that range of temperature where health and growth rate is optimal). Factors that dictate the thermal neutral zone include activity, insulation, plane of nutrition, and level of production (Bennett *et al.* 1985, Blackshaw and Blackshaw 1994).

Heat Stress

In describing heat and its effects on livestock an attempt should be made to define the term. The four environmental factors that should be considered when physical alteration of the environment is undertaken and which affect the effective temperature to which cows are exposed include: ambient temperature, relative humidity, air movement and solar radiation (Armstrong 1994). Gaughan *et al.* (1998) suggests that if optimum comfort and productivity are to be obtained by Holstein-Friesian dairy cows, shade will generally be required when the environmental temperature is above 30°C, however other climatic factors such as solar radiation and wind speed are also important. The chart devised by Wiersma in 1990 (Armstrong 1994) (Figure 1-8) shows the relationship between ambient temperature and relative humidity, illustrating degree of stress when cows are subjected to varying Temperature Heat Index.

Cows with a high percentage of black coats sought shade, while those with a high percentage of white coats did not seek shade (Gaughan *et al.* 1998). Provision of shade under hot conditions increases dry matter intake by 9.7% (Roman-Ponce *et al.* 1981), and increases feed intake (Silanikove and Gutman 1992), evidenced by a change in live weight and plasma free fatty acid levels.

In this context it is important to realise that the effects of warm weather can easily be confused with the effects of the changes in pasture quality that are a normal consequence of the higher temperatures during the relatively dry summer months.

High yielding cows have been shown to be more susceptible to heat stress than low yielders (West 1994), with greater declines in milk yield. Even in temperate regions, periodic times above the thermoneutral zone causing excessive heat load may cause serious short-term problems for cows not adapted to these conditions (Shearer and Beede 1990b). Certainly Hancock (1950a) considered that hot weather was unlikely to have much effect on grazing patterns in New Zealand conditions, because the weather during the dairying season is equable. However, he did observe some effects of hot conditions. In warm weather (24°C or over) the loafing time during the day of Holstein cows increased; the cows seemed uncomfortable and seldom lay down for any length of time.

Such weather also had the effect of dividing the grazing period that follows the afternoon milking into two parts separated by a period of lying. It was considered that this might be due to the need of rest as in many cases the cows had been walking or standing for over 13-hours.

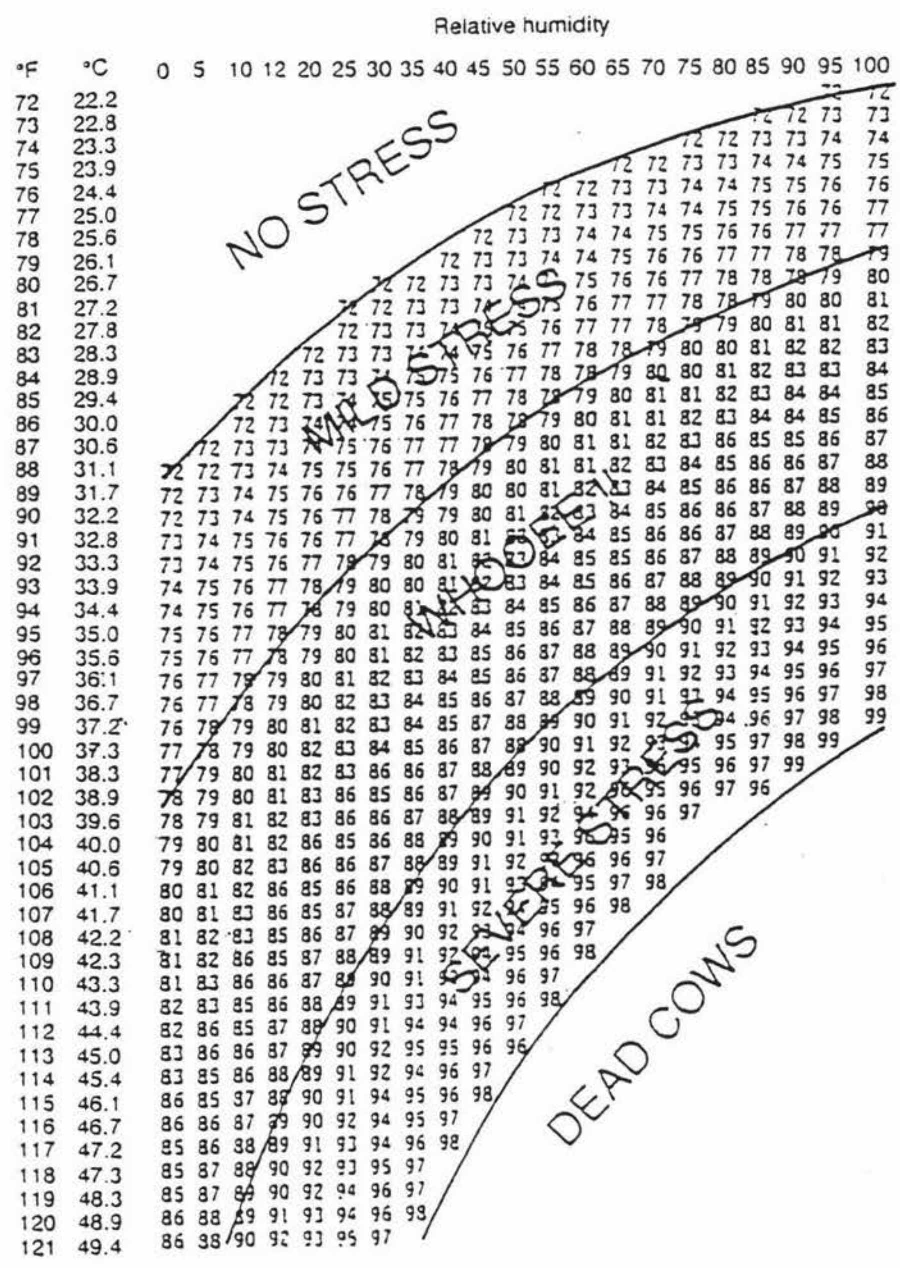

Figure 1-8 Temperature-humidity index table for dairy producer to estimate heat stress for dairy cows. Deg = Degrees. Relative humidity expressed as percentage. (From F. Wiersma, as adapted by Armstrong, 1994).

Cold Stress

The estimated range for highest efficiency of energy utilisation is from about 13 - 18°C. However, significant changes do not occur within the ranges of 5 - 25°C (NRC 1981). This range may be altered by type of feed, quality of feed, hair coat, stage of lactation and level of lactation. Blaxter (1964) showed that cold stress is greatly exacerbated by wind chill factors and by wetting of the hair coat.

Estimation of pasture availability

Introduction

Successful integration of rotational grazing into livestock farming requires estimates of the daily quantity and quality of pasture forage available for animal intake throughout the grazing season. Such information is valuable for feed budgeting and for calculations of stocking rate, both daily and for the season in relation to animal demand, existing on-farm forage reserves, and livestock production targets (Baars and Rollo 1987, Holmes 1989, Hodgson 1990). In rotational grazing systems, intake and daily pasture growth rate can be calculated from estimates of yield before and after grazing, if the individual grazing periods are short.

Mowing small areas of a site, weighing the grass, sub-sampling and determining the DM content provides an accurate method to measure DM yield. However, this method is destructive and labour intensive and therefore not useful on commercial dairy farms. Less tedious methods that do not require cutting would allow producers to take more measurements of herbage mass and expend less time in determining total pasture mass. During the last 25-years much effort has been expended in developing new techniques for estimating the dry matter yield in a non-destructive and accurate way. The three double sampling techniques whereby the results obtained from a small area by cutting are used to predict values derived indirectly from larger areas (Vilm *et al.* 1944) used most commonly are the rising-plate meter (RPM) (Holmes 1974, Earle and McGowan 1979), the single probe capacitance meter (Vickery *et al.* 1980), and visual assessment.

Assessment methods

Visual assessment

The first visual assessment technique acceptable in critical research was that of Pechanec and Pickford (1937) . It has since been used with numerous modifications and varying success (Wilm *et al.* 1944, Hutchinson *et al.* 1972, Campbell and Arnold 1973, Haydock and Shaw 1975, Baars and Dyson 1981).

The level of precision attributed to the visual assessment technique, and reported by others, has shown wide variations. One of its best performances was reported by Haydock and Shaw (1975), with a coefficient of variation of 10%, whereas others, such as Baars and Dyson (1981), have reported coefficients of variation as high as 38%. Stockdale (1984b) found the general level of precision of the technique for estimating pasture yields before grazing to be poorer than that generally reported for some of the other double sampling techniques, such as the capacitance meter and the RPM (Earle and McGowan 1979, Tucker 1980, Michell 1982). Relatively poor performance by observers when assessing post-grazing yields was observed. It has been found that the amount of pasture remaining after grazing by dairy cows is more difficult to estimate than pre-grazing yield because of the effects of trampling and the larger relative influence that dead material and litter at the base of the sward have on assessments (Baars and Dyson 1981).

Visual assessment can be used to estimate pre- and post-grazing pasture yields in dairy cow grazing experiments provided that sufficient reading are taken to allow an acceptable level of precision (Stockdale 1984). The major factors affecting the accuracy of the technique include the effects of fatigue and previous experience on subsequent visual assessments, and the variation between observers (Campbell and Arnold 1973). Adequate training can help to reduce these problems (Campbell and Arnold 1973, Thomson *et al.* 1997) by regular calibration with visual appraisals against measurements of total dry matter cut to ground level (Parker 1973).

Pasture Meters

Pasture meters are potentially useful devices for estimating herbage mass in grazed swards. Two such devices are the rising-plate meter (RPM) based on the Massey grassmeter (Holmes 1974) and the single-probe electronic capacitance meter (Vickery *et al.* 1980). The RPM has given useful results on swards of perennial ryegrass-white clover in winter and early spring (Earle and McGowan 1979, Michell 1982), but less accurate and more variable results are obtained on swards in summer (Michell 1982). The single-probe capacitance meter has given good results on Phalaris-white clover swards over the autumn to early spring period (Vickery *et al.* 1980).

ELECTRONIC CAPACITANCE METER

The principle is as follows. An oscillator in an electrical circuit produces a signal with a certain frequency. The frequency of the signal is influenced by a capacitor in the electrical circuit, with a change in capacitance of the capacitor resulting in a change in frequency. The capacitance of the capacitor depends on the dimensions of the two plates, the distance between the plates and the type of insulator (dielectric) between them. The aluminium pipe is one plate of the capacitor and the grass acts as the second plate. The air is the dielectric. The grass is in electrical contact with the meter through the ground and the aluminium pipe. The frequency of the signal of the oscillator in the atmosphere is the reference signal. In the grass, where the capacitance of the capacitor is higher than in the air, the frequency is lower (Gabriels and Berg 1993). The difference between the two frequencies can be read on a display and is called the corrected meter reading

RISING PLATE METER

The meter consists of a shaft and a square plastic or circular metal disc. When taking measurements the shaft is held vertically and placed in the grass. While the shaft is placed on the soil surface the disc stops going down when it settles on the grass. The distance between the disc and the soil surface, a measure of the height of the compressed grass, can be read of the marked part of the shaft. The position of the disc is determined by the height of the grass crop and by the density of the sward. The rising plate meter measures the canopy resistance, or the ability of the vegetation to repel compression or compaction when force is place upon it.

Earle and McGowan (1979) automated a rising plate meter (Figure 1-9) originally developed in New Zealand by Holmes (1974). The Ellinbank rising plate meter (RPM) (Earle and McGowan 1979) is commonly used to estimate pasture mass, and it is an improvement on using pasture height to determine pasture mass (Leaver 1982, Hodgson 1982) in that it measures height combined with density of the sward (Fulkerson and Slack 1993). It is simple in construction, lightweight and robust, and evaluations of its performance (Earle and McGowan 1979, Michell 1982) suggested that it estimates pasture yield with greater precision than is achievable by the visual assessment technique (Stockdale 1984).

Earle and McGowan (1979) concluded that the RPM performs with sufficient accuracy for research purposes, yet it is simple enough for farmers and their advisors to use as an aid to pasture management.

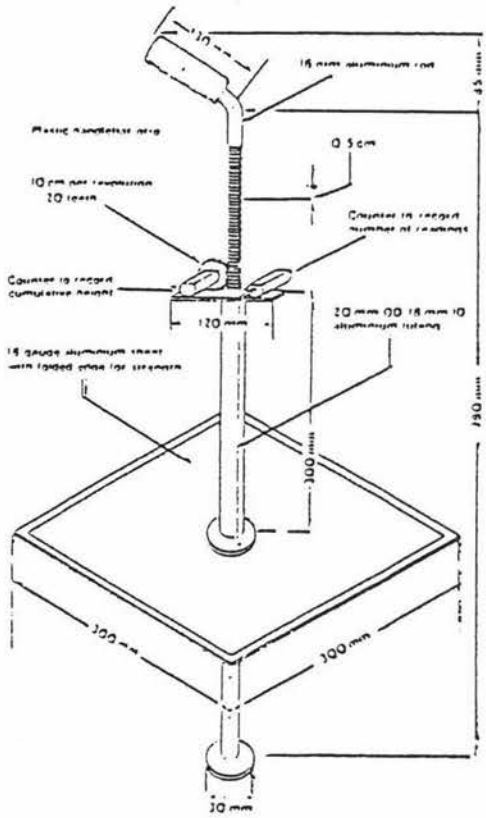

Figure 1-9 The Ellinbank Pasture Meter (Earle and McGowan 1979).

Variables

Pasture meter relationships

The relationships between herbage mass and meter readings were always linear for the capacitance meter (Vickery *et al.* 1980) and for the RPM (Michell 1982). Both meters gave readings that were more closely related to mass of herbage dry matter than mass of wet herbage or water. Sampling carried out over a range of weather conditions from showery to sunny and dry by Michell and Large (1983) showed no evidence of significant variation in capacitance meter reading.

Accuracy

The major source of error in herbage mass estimation is sampling error caused by within plot variability. The rising-plate meter has proved to be a useful instrument for overcoming this problem because a large number of readings can be taken quickly and easily. Michell (1982) always found a high correlation between meter reading and herbage mass. The relationship between RPM and herbage mass is normally constant between paddocks at any one time and often consistent over extended periods, even when given different managements (Michell 1982).

The accuracy of the rising plate meter to predict forage biomass is dependent on the forage type and species. Biomass of nonjointing grass species tends to be more highly predictable than biomass of jointing species (Harmoney *et al.* 1997). Fulkerson and Slack (1993) found the electronic pasture probe was less accurate in estimating Kikuyu or setaria pasture DM. Neither the capacitance meter nor the RPM are able to give accurate results with tall rejected herbage containing a build-up of senescent material (Michell and Large 1983). The RPM was found to be marginally more accurate than the capacitance meter because residual standard deviations were lower in all situations, and because the relationship was more stable over the spring. Neither meter could give accurate results of swards containing large amounts of unutilised senescent material. Fulkerson and Slack (1993) found no evidence that the probe differentiates 'quality' (green leaf) as suggested by Jones and Watkins (1965).

Thomson *et al.* (1997) showed the standard plate meter gave a reasonable estimate of average farm cover over a range of sites. With all meters, between-operator variability is small, provided correct operating procedures are followed (Fulkerson and Slack 1993). This contrasts with the large between-operator variability for visual estimates in the absence of calibration (r.s.d. = 767 v. 398-kg DM/ha for visual estimate without and with calibration, respectively (L'Huillier and Thomson 1988). Thomson *et al.* (1997) found a trained observer was able to assess herbage mass over a range of sites with a reasonable degree of reliability, similar to the reliability with a RPM.

L'Huillier and Thomson (1988) found a SE estimate of 350 to 450-kg DM/ha. Quadrat areas were selected to cover the range in herbage mass likely to be experienced at the time under dairy cow grazing (i.e. winter, 500 to 3000-kg DM/ha; summer, 1500 to 4000-kg DM/ha), with each quadrat area being measured by the RPM using two readings/quadrat. From the SE of pasture assessment, 50-80 estimates per paddock should be taken to obtain the most accurate estimate of herbage mass (Fulkerson and Slack 1993, Thomson *et al.* 1997). Ninety-eight percent of paddocks were ranked correctly within ±200-kg

DM/ha by either the corrected visual or standard plate meter (using the L'Huillier and Thomson (1988) equations for dairy pasture) assessments.

Measurements of pastures pre and post-grazing

The RPM and the probe provide similar precision in estimating pre and post-grazing residuals (Reeves *et al.* 1996) when measuring Kikuyu (*Pennisetum clandetinum*) pasture. When measuring *Paspalum dilatatum* pastures, Stockdale (1987) concluded that the RPM or single probe meter was more accurate for estimating pre-grazing yield than the visual assessment technique, but that the probe was more accurate post-grazing. This conclusion applied in situations in which trampling of the pasture was negligible, with the large effect of trampling on the post-grazing calibration regressions precluding the use of both pasture meters from general use in dairy cattle research (Stockdale 1987). In contrast measuring *Lolium perenne,* Gabriels and van den Berg (1993) found neither the RPM nor the probe to be good predictors of pre and post-grazing herbage mass.

Reeves *et al.* (1996) found pre-grazing calibration equations for the RPM determined at 2-weekly intervals differed significantly ($P<0.01$) from post-grazing calibrations when measuring Kikuyu (*Pennisetum clandetinum*) pasture. Consequently separate equations were used to determine pasture intake as the difference in pre- and post-grazing pasture mass.

Thomson *et al.* (1997) concluded that the most reliable on-farm estimations of pasture are average farm cover and paddock ranking to determine grazing order. Although the difference between pre- and post-grazing herbage mass is often used to calculate the amount of DM consumed, it was recommended this method be used with caution due to wide variability.

Meter repeatability throughout the day

Both the pasture probe and RPM are repeatable throughout the day on a fine day without early morning dew (L'Huillier and Thomson 1988). However, if weather conditions changed throughout the day (i.e. initially wet from a rainy or dew morning, but dry later) repeatability throughout the day was low (Figure 1-10). The use of appropriate calibrations for different climatic and pasture conditions significantly reduced this effect. Thus in wet conditions a calibration derived for wet pasture should be used to convert meter readings to herbage mass (kg DM/ha) (L'Huillier and Thomson 1988).

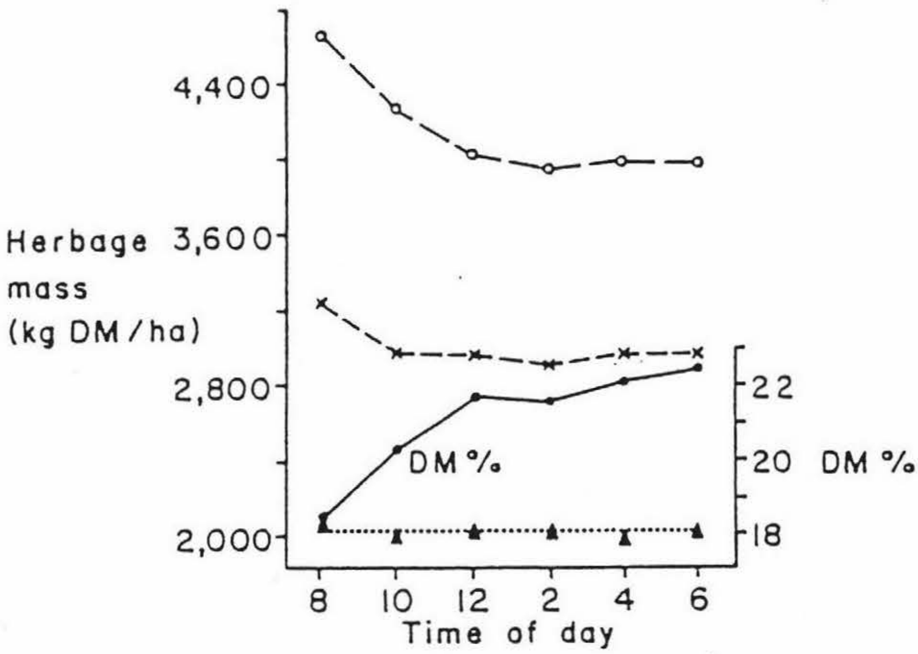

Figure 1-10 Change in herbage mass (HM) throughout the day (wet morning, fine later) for each of three levels of HM and mean dry matter content of herbage (•_•). Mean of probe and RPM methods. (L'Huillier and Thomson 1988)

Operator

Little difference occurs between calibrations for different users of both the probe and RPM, if the correct procedures are followed (L'Huillier and Thomson 1988). Thus if an inexperienced operator held the meters in an upright position and cleaned and checked the meters regularly (including waxing the probe), the results are likely to be similar to values obtained by an experienced operator. In contrast, the operator had some effect on the accuracy (measured by RSD) of herbage mass estimations by visual assessment. Similarly, visual assessment in pastures containing species unfamiliar to the operators can introduce large errors (Thomson 1986). Observers trained for the specific conditions, and the plate meter using a standard calibration equation, assess herbage mass with similar accuracy (Thomson *et al.* 1997).

Season and site

The capacitance meter, like the rising-plate meter, does not measure herbage dry matter mass directly but rather some factor that is related to herbage mass only within seasons This is indicated by capacitance meter relationships showing a change in slope during spring, and another change to a constant level over summer (Michell and Large 1983). L'Huillier and Thomson (1988) observed no difference between dairy pastures in

Taranaki and the Waikato in the relationships between rising plate meter reading, pasture height and pasture probe measurements, and herbage mass cut to ground level. However they did find large variation in calibrations between and within seasons.

Dead material content or mass is the only factor that has any effect on calibration variation (L'Huillier and Thomson 1988). This suggested that green herbage mass was a more "measurable" component by methods such as the probe, RPM and height, than total herbage mass. Green herbage mass was also thought to be more closely related to animal performance. Factors such as soil surface moisture and/or climate (temperature and humidity) may have had some influence of variation among calibrations. Variation among calibrations within a season was least during winter-early spring and greatest during summer and autumn. On the basis of minimising the increase in RSD from pooling the data, L'Huillier and Thomson (1988) identified five seasonal calibrations which are still considered to be appropriate 10 years later (Thomson *et al.* 1997).

L'Huillier and Thomson (1988) fitted an equation to the data so that a slope could be calculated for any day of the year. This slope, together with a constant intercept, then forms the calibration. This procedure has the advantage that the calibration changes gradually throughout a season in a similar fashion to the original data, and is thus slightly more accurate than seasonal calibrations. This method, however, involves more calculations to derive the calibration equations. Seasonal calibration equations for the pasture probe, RPM and sward height are recommend for on-farm estimation of herbage mass in ryegrass/white clover dairy pastures (Livestock Improvement Advisory and Dairying Research Corporation Limited 1999).

Effect of summer irrigation of the relationship

Michell (1982) compared calibration equations for irrigated and non-irrigated paddocks, with there being no significant differences in calibration between irrigated and non-irrigated paddocks. It appears therefore; that it is not necessary to develop separate calibration equations for irrigated versus non-irrigated swards and indicates that no difference in summer calibration is likely between years because of different rainfall patterns (Michell 1982).

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CHAPTER 2

Seasonal behaviour of grazing dairy cattle, effects of season of calving, season of the year, and maturity of the pastures

Abstract

Two experiments were carried out during the spring (September) and early summer (December) of 1998 at Number 1 Dairy Farm, Massey University, Palmerston North. The purpose was to measure the effects of stage of lactation and season of the year on the grazing behaviour of Holstein-Friesian cows that had calved in the autumn or spring. EXP1 used 22 spring and 22 autumn calving cows, and EXP2 42 spring calving and 42 autumn calving cows. Both trials were two weeks in length, and experimental cows were grazed with their respective herd mates. Grazing, ruminating and idling activities were recorded every 10 to15-minutes for 3 (EXP1) or 2 (EXP2) grazing periods, each of 24-hours duration. In addition bite rates were recorded for individual cows during these periods at the peak grazing times of 8-am, midday, and 4-pm. Dry matter intake was not significantly different between EXP1 (15.9-kg DM/cow/day) and EXP2 (16.6-kg DM/cow/day), however milk production (1.52 *vs.* 1.19-kg MS/cow/day; P<0.001) was lower, and live weight (487 *vs.* 514-kg; P<0.01) was higher in EXP2. Total grazing times (590 *vs.* 521-minutes; P<0.001), ruminating times (352 *vs.* 462-minutes; P<0.001), and idling times (254 *vs.* 225-minutes; P<0.001) respectively for EXP1 and EXP2 also differed between experiments. Cows in EXP1 had faster bite rates (57 *vs.* 50-bites/minute; P<0.001), smaller bites (485 *vs.* 662-mg DM/bite; P<0.001) and had a lower intake rate (27 *vs.* 32-g DM/min; P<0.001), but higher total DMI than in EXP2. Differences in grazing behaviour and bite characteristics between EXP1 and EXP2 were consistent for the autumn and spring calvers, suggesting sward characteristics and not stage of lactation, were the main contributing factor. Cows preferred to graze during the day, spending a consistent 47-50% of daylight hours grazing, with whatever remaining grazing required done at night. Heifer grazing, ruminating and idling times, and patterns were similar to those of the mature cows, despite a smaller herbage intake (14.1 *vs.* 17.1-kg DM/cow/day; P<0.01) respectively for heifers and mature cows in December. Heifers had a consistently smaller bite weight than mature cows. Lactating dairy cows grazing behaviour remains consistent throughout the year, in that they prefer to graze during daylight hours, but as they can only spend around 50% of the time grazing, are required to always graze at night to some extent. Bite characteristics such as bite rate, bite weight, and intake rate are more related to sward characteristics than stage of lactation. Mature cows are more readily able to increase their herbage intake rate under ideal conditions than heifers, and choose to graze for less time rather than increase their total intake.

Heifers are not willing to graze longer than the mature cows (although theoretically able), to make up for their lower rate of intake.

Introduction

Many experiments have measured grazing, ruminating, and idling times, although theories to explain variation in these behavioural variables are less common. The three major factors affecting time allocation are animal state (Penning *et al.* 1995), herbage quality (Penning *et al.* 1991b) and herbage availability (Penning *et al.* 1991a). In particular, animals with high energy demands reduce their idling time to achieve higher daily intake (Penning *et al.* 1995). In addition, as quality of forage declines during grazing down into the sward (Hendricksen and Minson 1980), longer processing (rumination) time is required per gram ingested. Sheep and cattle also increase their grazing time as herbage availability declines, in an effort to meet their intake requirements (Allden and Whittaker 1970).

Animal state is reflected indirectly through bite weight, since animals with higher energy demands are less selective, take larger bites (Newman *et al.* 1994), masticate for shorter periods but graze for longer periods (Penning *et al.* 1995). Several studies have shown that the time required to prehend a bite is constant despite differences in bite weight (Laca *et al.* 1994, Penning *et al.* 1995). In contrast, mastication time has been found to be approximately proportional to the quantity of material ingested with each bite. Social factors such as group size also effect grazing behaviour (Penning *et al.* 1993).

Animals grazing at high pasture allowance may reduce their grazing time if their energy requirements are satisfied (Penning *et al.* 1991a). However, grazing on grass pasture is an energy intensive activity, with small marginal rates of energy gain, (Woodward 1997), so satiety may not be observed often in practice. Jamieson and Hodgson (1979) suggested animals managed in an intensive rotational grazing system anticipate future access to new feed after milking, and hence become restless and graze intermittently in the final period just before milking.

This chapter reports the results of two experiments carried out with autumn and spring-calved cows in early-mid lactation (September (EXP1)), and mid-late lactation (December (EXP2)) in 1998. It was intended to measure the effect of stage of lactation, and season on grazing behaviour and bite characteristics of mature cows and heifers.

Materials and Methods

Farm details

The dairy farm at the Massey University Number 1 Dairy Unit is part of the original Bachelor Estate purchased for the establishment of Massey Agricultural College in 1927. The Friesian dairy herd was established in 1929, with the farm producing winter milk for the last 40 years. Number 1 Dairy Farm comprises 123.5 effective hectares, and grazes 130 autumn calving cows and 150 spring calving cows. The farm was split into 3 farmlets of approximately 40-ha comprising of a 100% autumn, 100% spring calving herd, and a 50:50 calving herd, with each unit operated as an independent, self-contained unit managed to optimise its production and profitability. Detail on the formation of these herds has been given by Garcia *et al.* (1998). General farm statistics including production levels are shown in Table 2-1.

Table 2-1 Massey University Number 1 dairy farm information – 1997/1998 season.

	100% Autumn calving herd	*100% Spring calving herd*	*50% Autumn calving herd*	*50% Spring*
Number cows (peak milk)	80	100	48	48
Area	40.1	40.0	42.6	
Stocking rate (cows/ha)	2.0	2.5	2.25	
Planned start of calving	10 March	20 July	20 March	1 August
Planned start of mating	1 June	10 October	10 June	22 October
Production (kg MS/cow)	362	311	328	
Production (kg MS/ha)	721	785	739	

The pastures are predominantly rye grass/white clover for most of the year, and are utilised mainly by lactating cattle using rotational grazing. The soil is classed as recent river soils (Rangitikei and Manawatu Series), which is moderately to well drained, drought prone and medium to high natural fertility. The average annual pasture production is 11-tonne DM per hectare, with an average rainfall of 995-mm. Any grass surpluses are cut for silage and supplementary feeds are fed in the form of grass and maize silage.

Animals and management

Lactating autumn (A) and spring (S) calving Holstein-Friesian cows from the Number 1 Dairy Farm, Massey University, were used in two short-term grazing experiments in the spring (September) (EXP1) and summer (December) (EXP2) of 1998. Cows were balanced by age, parity, days in milk and yield of milksolids. During EXP1 22 S early lactation and 22 A mid lactation cows were used from the split-calving herd. In EXP2 a total of 42 S mid lactation cows (22 from the split-calving herd and 20 from the 100% spring-calving herd) and 42 A late lactation cows (22 from the split-calving herd, and 20 from the 100% autumn calving herd) were used. Each trial lasted two weeks, and 43 cows out of the 44 cows used in EXP1 were used again in EXP2. In addition half the cows in each trial were dosed with Rumensin, with this being distributed equally between autumn and spring calved cows. During the grazing trials, the experimental animals were rotationally grazed with their respective main herds. In each experiment the cows were offered a generous daily herbage allowance between 40 to 65-kg DM/cow as assessed by a rising plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand). Cows were offered their daily herbage allowance as a new paddock after milking, at the beginning of each 24-hour measurement period.

Pastures

Predominately perennial ryegrass-white clover pastures (comprising more than 70% of the herbage dry matter) were grazed. The herds level of feeding was estimated indirectly by measuring pre and post-grazing herbage masses from 100 readings of pasture height using a rising plate meter (Michell, 1982), and the area allocated daily for grazing. Daily herbage allowance was calculated from the expression given by Milligan *et al.* (1987) as:

$$\text{Herbage allowance (kg DM/cow/day)} = \frac{[\text{Pre-grazing pasture mass (kg DM/ha)}] \times \text{Area grazed per 24 hours}}{\text{Number of cows}} \quad [2.1]$$

Pre-grazing and post-grazing pasture mass (kg DM/ha) was estimated using the September equations of kg DM/ha = 124x + 821 (Chapter 4) for EXP1, and the December derived equation of kg DM/ha = 85x + 1959 (EXP2); where x is the value measured by the rising plate meter.

Measurements Recorded

Live weight, condition score

On one day per month, cows were weighed after the afternoon milking using electronic scales (Tru Text, New Zealand Ltd) and their body condition was assess visually, on a scale 1 (thin) to 9 (fat) (Holmes and Wilson 1987).

Yield of milk

Cows were milked twice daily at approximately 06.00 and 15.30-h. On one day during the two-week trial period, aliquots of milk samples were collected from each cow on two consecutive milkings, and the samples were weighed to measure milk yields and analysed to measure the concentrations of fat, protein and somatic cells.

Herbage Intake and digestibility

These are part of another study by Dr Gerald Cosgrove, AgResearch. Only the main results will be published here, and discussed in relation to grazing behaviour.

Faecal samples were taken from the ground while the cows were grazing at pasture after morning milking so as to minimise disturbance to the cows. Intake was based on faecal samples taken on two periods of five consecutive days each, days 7-11 and 14-18. Samples within each 5-day period were freeze dried, ground, and pooled on an equal-dry weight basis prior to analysis.

Herbage samples were taken from each paddock grazed during each period to simulate the diet and freeze dried and pooled on such a basis so that each paddock was represented in the sample in the same proportion as it contributed to the feed allocation in that period. Herbage samples were plucked to anticipate grazing height from several areas around the paddock to represent the herbage consumed.

Grazing behaviour

Grazing behaviour on pasture was monitored during three separate periods, each of 24-hours in EXP1 and two separate periods, each of 24-hours in EXP2, with at least one of these occurring in each 5-day sub-period when intakes by individual cows were measured using the alkane technique (Mayes *et al.* 1986). Observers were trained prior to the recording of the information, and allocated working shifts of no more than three hours to avoid fatigue. Nocturnal observations were aided by using a spotlight, and by painting the cow's identification number on the flanks and rumps using fluorescent or enamel paint. Additionally the cow number was repeatedly written on Fluorescent Velcro collars, attached around cows' necks. These latter proved to be particularly successful, as the paint tended to be rubbed off with mating, milking, and rain. The animals were accustomed to the presence of observers, and only minor disturbances in their pattern of grazing behaviour were expected and observed. Grazing, ruminating and idling times were estimated by recording the grazing activity of individual cows every ten minutes during daylight hours, and every fifteen minutes at night (Hodgson 1982). Animals were considered to be grazing when their heads were down to the ground, and they were biting, searching or chewing (Cazcarra and Petit 1995). Grazing activities were recorded in September by the observer adding the appropriate letter into the grazing observation sheet (Inwood *et al.* 1992) shown in Appendix 2.1. The December grazing observation sheet changed slightly, with observers being required to cross out the inappropriate letters printed on the sheet in Appendix 2.2. This removed the problem of deciphering observers' handwriting.

During the period of faeces collection, biting rate was also measured on all cows. Biting rates were recorded three times per day at peak grazing hours in the morning (8:00 to 9:00-a.m.), at noon (12:00 to 13:00-p.m.), and in the afternoon (17:00 to 18:00-p.m.). Within each one-hour observational period, two consecutive records of biting rate were obtained from each cow by counting the number of bites taken in one minute (Hodgson 1982). Biting rates (number of bites/min) for each hour of the day were calculated for each cow from the average of the two consecutive records. Sound and movement of the head when cutting grass defined a grazing bite, and records were discarded if the animal failed to graze for more than one minute as defined above.

Derived variables

Bite weight and rate of intake

For each five-day period of intake determination, bite weight (mg DM/bite), and rate of intake (mg DM eaten/minute) were calculated for each cow from the available records of biting rate and dry matter intake using the following equation (Hodgson 1982):

$$\text{DMI} = \text{GT} \times \text{BR} \times \text{BS} \qquad [2.4]$$

Where DMI is the dry matter intake (kg/cow/day) as assessed by the *n*-alkanes technique; GT is the total grazing time (minutes/day) recorded during the 24-hour grazing behaviour observational periods; BR is the average of the biting rate records taken during the day, and BS is bite size (g DM/bite). From equation [2.4], mean individual bite weight was calculated from DMI divided by the total number of daily bites, estimated as the product of grazing time and biting rate. Intake rate was estimated as daily intake divided by daily grazing time (Hodgson 1982).

Statistical Analysis

Data were analysed using PRC GLM (SAS Institute 1990). Data for LW, milksolids yield, and the parameters of grazing behaviour (grazing time, ruminating time, idling time, biting rate, total bites per day, bite weight and rate of intake) were analysed using Least Squares Means. A comparison was run between months, however analysis was done by month for heifer *vs.* mature cows, and spring *vs.* autumn calved cows, and Rumensin *vs.* non-Rumensin dosed cows. Interactions between calving season and maturity level, Rumensin and calving season, and Rumensin and maturity levels were tested.

Results

Sward variables and herd averages

The average sward conditions during EXP1 and EXP2 and the results of the chemical analyses of the pasture are summarised in Table 2-2, together with milk production by the herd. Apparent intake by the herd was calculated from the difference between herbage mass present before and after grazing as assessed by the rising plate meter. Results are summarised as means and standard deviations for the sward variables and as single values for the grass nutritive value. Figure 2-1 and Figure 2-2 show the average sward heights recorded during the course of EXP1 and EXP2.

Table 2-2 Means and standard deviations for pasture variables recored during EXP1 and EXP2.

Variable	*EXP1*	*EXP2*
Herd milk production (kg MS/cow/day)	1.52 ± 0.33	1.31± 0.27
Herbage mass (kg DM/ha)		
Pre-grazing	2879 ± 358	3387 ± 174
Post-grazing	1990 ± 239	2847 ± 99
Daily herbage allowance		
kg DM/cow	55.2 ± 13.6	57.6 ± 18.4
Herbage disappearance rate (apparent intake) (kg/cow/day)	16.8 ± 5.0	8.4 ± 2.6
Digestibility		
Dry matter (%)	13.7 ± 2.1	14.0 ± 2.4
Organic matter digestibility (g/100 g DM)	87.7 ± 2.6	71.3 ± 3.4
Estimated ME (MJ/kg DM)	12.2 ± 0.4	10.6 ± 0.5
Fibre		
ADF (g/100 g DM)	20.3 ± 0.8	27.3 ± 1.4
NDF (g/100 g DM)	40.5 ± 1.5	48.9 ± 2.7
Crude protein (g/100g DM)	30.1 ± 2.5	19.0 ± 2.0

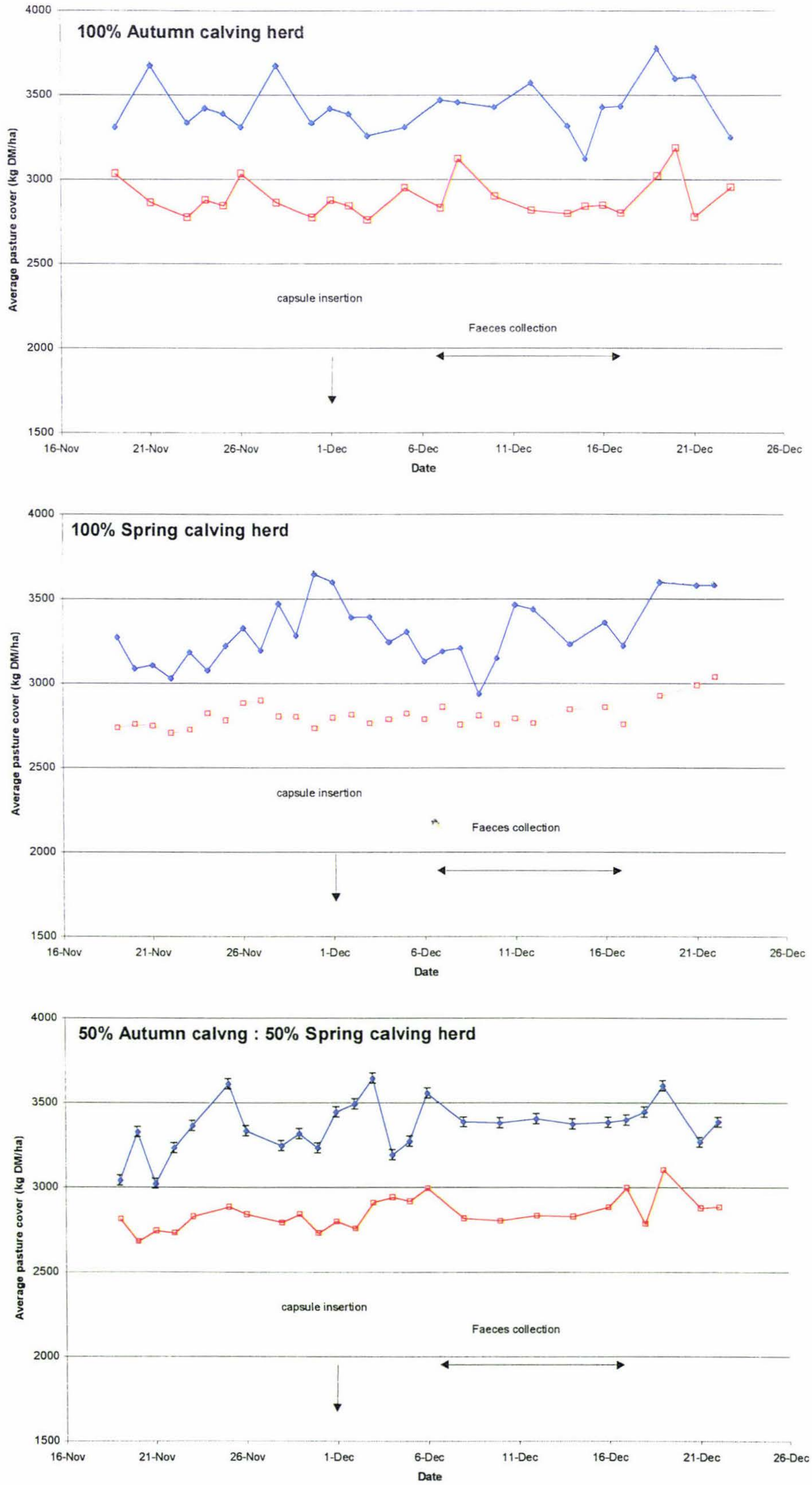

Figure 2-1 Means for pre-grazing (◆) and post-grazing (□) sward surface height recorded during EXP2 for the three herds used.

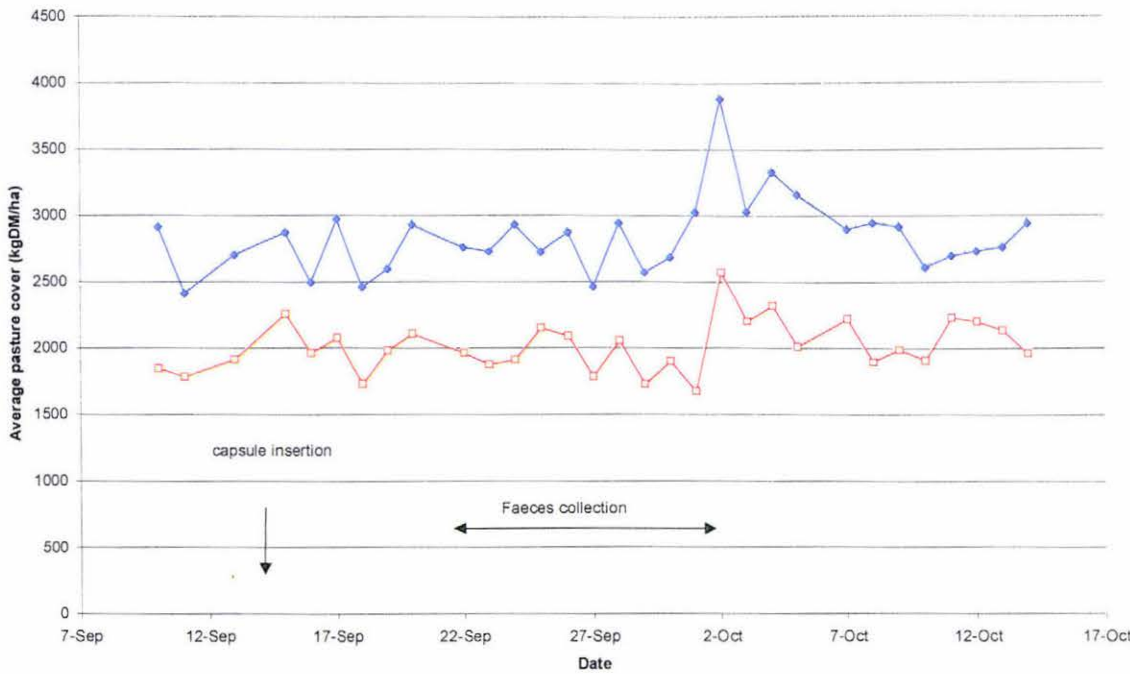

Figure 2-2 Means for pre-grazing (♦) and post-grazing (□) sward surface height recorded during EXP1.

Grazing behaviour

Grazing time, ruminating time and idling time

The distribution of grazing, ruminating and idling times during the 24-hour periods in September (EXP1) and December (EXP2) are given in Figure 2-3. In EXP1 about 59% of the grazing activity occurred during the 12-hours of daylight, with corresponding values for EXP2 (15-hours daylight) being 85%. The pattern of grazing was very similar in both experiments with distinctive peaks of grazing activity just after the morning and afternoon milkings. The relationships between milk solids production, herbage intake, and total grazing time per day are shown in Table 2-3, and Table 2-4.

No effect of Rumensin was found on the grazing behaviour of the cows. Results from the analysis of the grazing, ruminating, and idling times (night, day, and total) are given between herds (Table 2-5), for heifers *vs.* mature cows by month (Table 2-6 and Table 2-7), and for autumn *vs.* spring calved cows by month in Table 2-8 and Table 2-9. The cows in EXP1 had significantly ($P<0.001$) longer grazing and idling times, and reduced ruminating time than in EXP2. Heifers grazing behaviour was similar to that of mature cows, despite significantly ($P<0.05$) less DM intake in EXP2. In EXP1 autumn calvers grazed for less time ($P<0.01$), and idled for longer ($P<0.001$) than the spring calvers, whereas in EXP2 the distribution of night and day grazing was different, but total grazing intake was similar for the autumn and spring calvers. In EXP2 the autumn calving cows spent less time ruminating ($P<0.001$) and more time idling ($P<0.001$) than the spring calving cows. No interactions were found between calving season and maturity level, Rumensin and calving season, and Rumensin and maturity levels at the 10% level.

Biting characteristics

Cows in EXP1 showed significantly faster rates of biting than in EXP2, and combined with their longer grazing time, they also showed significantly higher number of total bites per day. Cows from EXP1 also took significantly more smaller bites per kg of DM eaten than those in EXP2, leading to a smaller intake rate of dry matter per minute. Heifers showed a significantly larger number of bites per kg of DM eaten, and per kg of MS produced, reflected in their smaller bite weight of DM per bite in both EXP1 and EXP2.

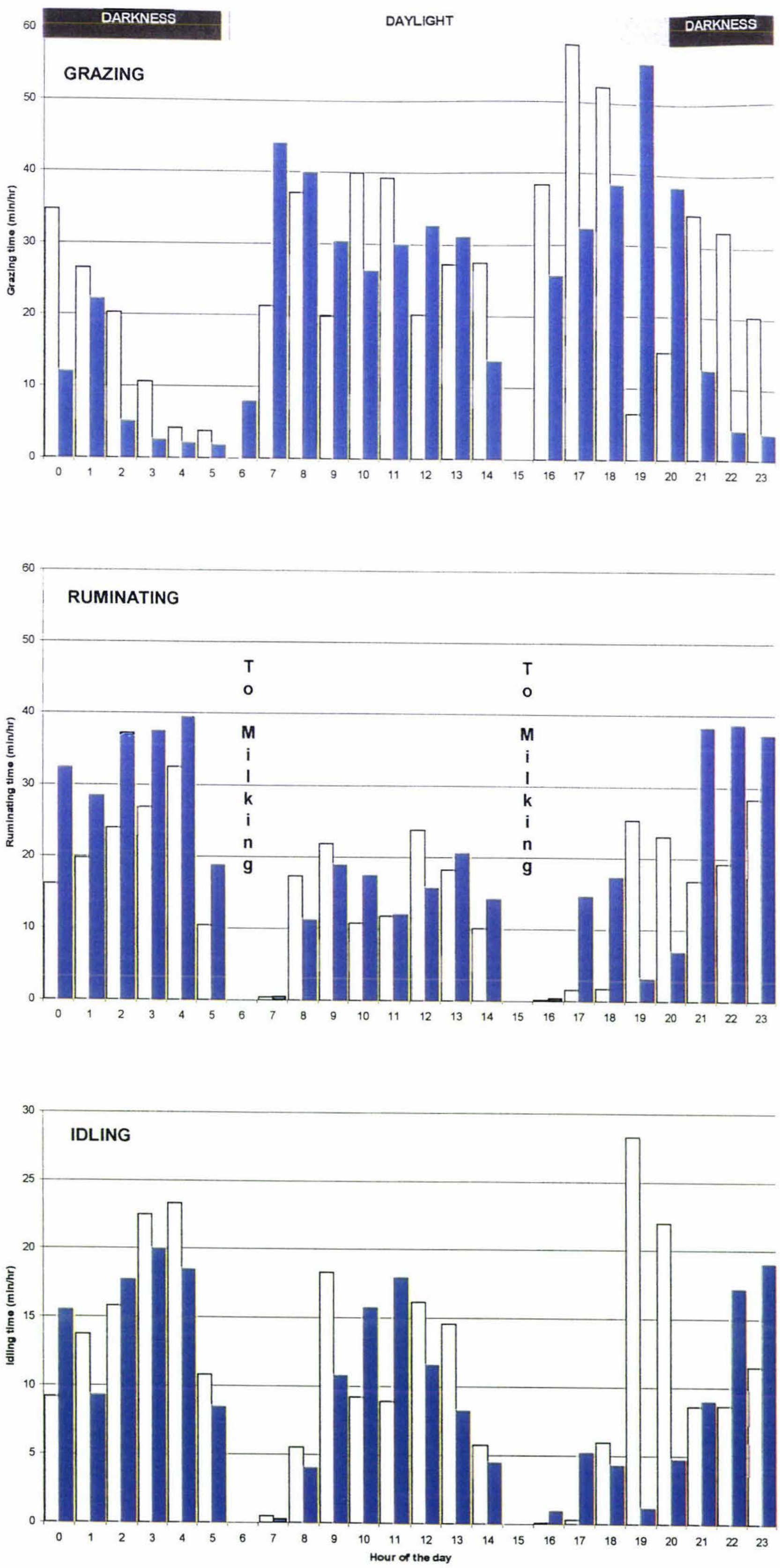

Figure 2-3 Mean grazing, ruminating and idling times during 24-hour observational periods for September (□) and December (■) by grazing cows offered generous herbage allowances. The grey shaded areas represent the difference in daylength between September and December, with December averaging 2 ½ hours more daylight per day.

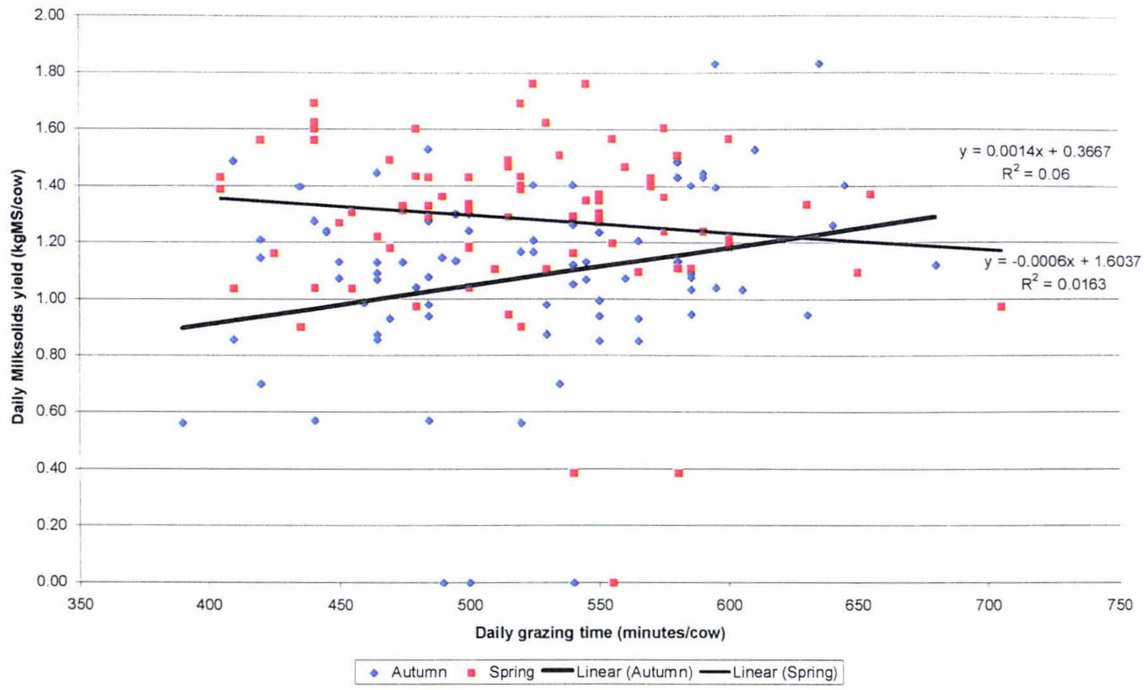

Table 2-3 The relatinship between daily milksolid yield and day grazing time for individual cows in EXP2.

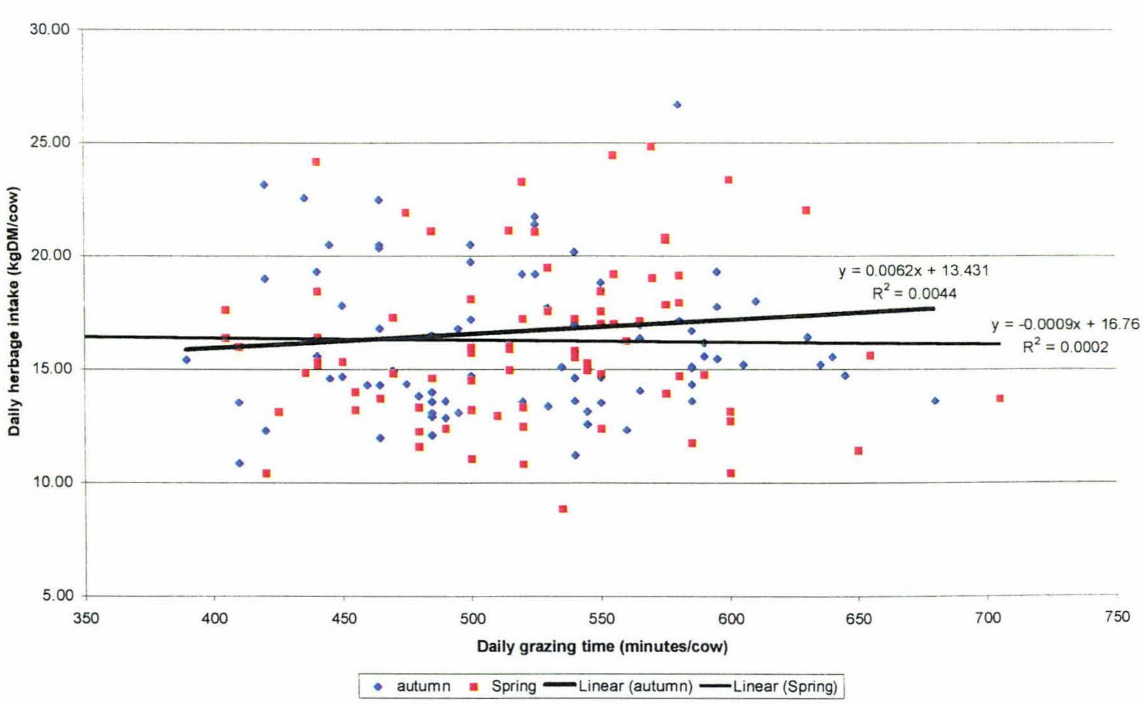

Table 2-4 The relation between day herbage intake and grazing time for individual cows in EXP2

Table 2-5 Least squares means (±SE) for parameters of ingestive behaviour of autumn and spring calved cows offered generous herbage allowances during September (EXP1) and December (EXP2).

tem[1]	*Group*				
	EXP1 (September)	n	EXP2 (December)	n	Significance[2]
Daily intake (kg DM per cow)					
Pasture[3]	15.9 ± 0.42	130	16.6 ± 0.37	162	NS
Milk Production (cow/day)					
Kg MS (cow/day)	1.52 ± 0.03	130	1.19 ± 0.03	162	***
Liveweight (kg)	487 ± 6.0	123	514 ± 7.5	79	**
Grazing time (min/day)					
Day	348 ± 5.0	131	443 ± 4.5	163	***
Night	240 ± 4.5	132	79 ± 4.0	163	***
Total	590 ± 5.7	131	521 ± 5.1	163	***
Ruminating time (min./day)					
Day	116 ± 4.7	131	149 ± 4.2	163	***
Night	238 ± 4.8	132	312 ± 4.3	163	***
Total	352 ± 5.5	131	462 ± 4.9	163	***
Idling time (min./day)					
Day	80 ± 2.9	131	87 ± 2.6	163	†
Night	174 ± 4.3	132	138 ± 3.9	163	***
Total	254 ± 5.3	131	225 ± 4.7	163	***
Biting rate (bites/min.)	57 ± 0.5	339	50 ± .5	394	***
Total bites (bites/day)	33727 ± 447.8	131	25832 ± 410.4	156	***
Number of bites per					
kg of DM eaten	2220 ± 45.7	127	1655 ± 41.3	155	***
kg of MS	22723 ± 561.9	125	21919 ± 511.2	151	NS
Bite weight of pasture					
mg DM/bite	485 ± 16.94	127	662 ± 15.34	155	***
mg DM/kg $LW^{0.75}$	4.7 ± 0.15	118	5.7 ± 0.19	76	***
Intake rate – pasture					
g DM/min.	27 ± 0.83	127	32 ± 0.75	155	***
mg DM/kg $LW^{0.75}$/min.	265 ± 7.42	118	280 ± 9.25	76	NS
Grazing time per kg DM eaten	38.6 ± 0.74	127	33.4 ± 0.65	162	***

[1] Sunrise: September: 6 a.m. ; December: 5.45 a.m.

[1] Sunset: September: 6.20 p.m. ; December: 8.40 p.m.

[2] NS = not significant; † = P<0.1; * = P<0.05; ** = P< 0.01; *** = P<0.001.

[3] Pasture intake calculated from n-alkane method.

Table 2-6 EXP1 (September) least squares means (±SE) for parameters of ingestive behaviour of autumn and spring calved cows and heifers offered generous herbage allowances.

Item	*Group*				
	Mature	n	Heifer	n	Significance
Daily intake (kg DM per cow)					
Pasture[3]	16.0 ± 0.38	113	15.1 ± 1.06	15	NS
Milk Production (cow/day)					
Kg MS (cow/day)	1.55± 0.04	115	1.32 ± 0.12	15	†
Liveweight (kg)	498 ± 5.7	108	408 ± 15.3	15	***
Grazing time (min/day)					
Day	348 ± 5.4	116	352 ± 15.0	15	NS
Night	240 ± 5.6	117	244 ± 15.5	15	NS
Total	589 ± 6.5	116	596 ± 18.1	15	NS
Ruminating time (min./day)					
Day	116 ± 4.2	116	113 ± 11.6	15	NS
Night	239 ± 5.2	117	230 ± 14.6	15	NS
Total	354 ± .4	116	342 ± 17.8	15	NS
Idling time (min./day)					
Day	80 ± 3.0	116	80 ± 8.5	15	NS
Night	174 ± 4.8	117	177 ± 13.4	15	NS
Total	254 ± 6.1	116	257 ± 16.9	15	NS
Biting rate (bites/min.)	56 ± 0.5	307	60 ± 1.6	32	*
Total bites (bites/day)	33413 ± 507.5	116	36163 ± 1411.4	15	†
Number of bites per					
kg of DM eaten	2186 ± 52.6	112	2474 ± 143.6	15	†
kg of MS	2072 ± 87.7	110	27497 ± 1592	15	**
Bite weight of pasture					
mg DM/bite	493 ± 13.77	112	423 ± 37.63	15	†
mg DM/kg $LW^{0.75}$	4.7 ± 0.13	103	4.7 ± 0.35	15	NS
Intake rate – pasture					
g DM/min.	27 ± 0.69	112	26 ± 1.88	15	NS
mg DM/kg $LW^{0.75}$/min.	263 ± 6.53	103	281 ± 17.11	15	NS
Grazing time per kg DM eaten	38.3 ± 0.76	112	41 ± 2.09	15	NS

[1]Sunrise: September: 6 a.m. ; December: 5.45 a.m.

[1]Sunset: September: 6.20 p.m. ; December: 8.40 p.m.

[2]NS = not significant; † = P<0.1; * = P<0.05; ** = P< 0.01; *** = P<0.001.

[3] Pasture intake calculated from n-alkane method.

Table 2-7 EXP2 (December) least squares means (±SE) for parameters of ingestive behaviour of autumn and spring calved cows and heifers offered generous herbage allowances.

Item	*Group*				
	Mature	n	Heifer	n	Significance
Daily intake (kg DM per cow)					
Pasture[3]	17.1± 0.44	135	14.1 ± 0.99	27	**
Milk Production (cow/day)					
Kg MS (cow/day)	1.22 ± 0.03	136	1.03 ± 0.06	26	**
Liveweight (kg)	524 ± 8.1	64	470 ± 16.8	15	**
Grazing time (min/day)					
Day	441 ± 4.9	136	448 ± 11.0	27	NS
Night	80 ± 3.7	136	74 ± 8.2	27	NS
Total	522 ± 5.3	136	521 ± 11.9	27	NS
Ruminating time (min./day)					
Day	150 ± 5.1	136	143 ± 11.5	27	NS
Night	312 ± 4.7	136	311 ± 10.5	27	NS
Total	463 ± 5.0	136	455 ± 11.2	27	NS
Idling time (min./day)					
Day	86 ± 2.9	136	90 ± 6.5	27	NS
Night	136 ± 4.1	136	145 ± 9.2	27	NS
Total	223 ± 4.8	136	234 ± 10.8	27	NS
Biting rate (bites/min.)	50 ± 0.5	329	51 ± 1.2	65	NS
Total bites (bites/day)	25797 ± 421.6	129	26003 ± 921.6	27	NS
Number of bites per					
kg of DM eaten	1606 ± 40.8	128	1887 ± 88.9	27	**
kg of MS	21207 ± 537.6	125	25344 ± 1178.7	26	**
Bite weight of pasture					
mg DM/bite	684 ± 19.10	128	558 ± 41.58	27	**
mg DM/kg $LW^{0.75}$	5.8 ± 0.27	61	5.6 ± 0.54	15	NS
Intake rate – pasture					
g DM/min.	33 ± 0.94	128	28 ± 2.04	27	*
mg DM/kg $LW^{0.75}$/min.	285 ± 12.69	61	261 ± 25.59	15	NS
Grazing time per kg DM eaten	52.5 ± 0.71	135	38.1 ± 1.58	27	**

[1]Sunrise: September: 6 a.m. ; December: 5.45 a.m.

[1]Sunset: September: 6.20 p.m. ; December: 8.40 p.m.

[2]NS = not significant; † = P<0.1; * = P<0.05; ** = P< 0.01; *** = P<0.001.

[3] Pasture intake calculated from n-alkane method.

Table 2-8 EXP1 (September) least squares means (±SE) for parameters of ingestive behaviour of autumn and spring calved cows offered generous herbage allowances.

Item	*Group*				
	Autumn	n	Spring	n	Significance
Daily intake (kg DM per cow)					
Pasture[3]	15.4 ± 0.51	64	16.3 ± 0.51	64	NS
Milk Production (cow/day)					
Kg MS (cow/day)	1.32 ± 0.05	64	1.72 ± 0.05	66	***
Liveweight (kg)	509 ± 8.0	60	465 ± 7.9	63	***
Grazing time (min/day)					
Day	343 ± 7.1	66	354 ± 7.2	65	NS
Night	228 ± 7.2	66	253 ± 7.2	66	*
Total	571 ± 8.3	66	609 ± 8.4	65	**
Ruminating time (min./day)					
Day	113 ± 5.5	66	118 ± 5.6	65	NS
Night	231 ± 6.9	66	244 ± 6.9	66	NS
Total	344 ± 8.4	66	361 ± 8.5	65	NS
Idling time (min./day)					
Day	87 ± 3.9	66	72 ± 4.0	65	**
Night	193 ± 5.9	66	155 ± 5.9	66	***
Total	280 ± 7.4	66	227 ± 7.4	65	***
Biting rate (bites/min.)	56 ± 0.7	170	57 ± 0.7	169	NS
Total bites (bites/day)	32553 ± 665.6	66	34920 ± 670.7	65	*
Number of bites per					
kg of DM eaten	2188 ± 70.4	64	2252 ± 71.0	63	NS
kg of MS	23988 ± 812.9	60	21556 ± 781.0	65	*
Bite weight of pasture					
mg DM/bite	483 ± 18.44	64	487 ± 18.58	63	NS
mg DM/kg $LW^{0.75}$	4.6 ± 0.18	58	4.9 ± 0.17	60	NS
Intake rate – pasture					
g DM/min.	27 ± 0.91	64	27 ± 0.92	63	NS
mg DM/kg $LW^{0.75}$/min.	255 ± 8.65	58	274 ± 8.50	60	NS
Grazing time per kg DM eaten	38.1 ± 1.01	64	39.2 ± 1.02	63	NS

[1]Sunrise: September: 6 a.m. ; December: 5.45 a.m.

[1]Sunset: September: 6.20 p.m. ; December: 8.40 p.m.

[2]NS = not significant; † = P<0.1; * = P<0.05; ** = P< 0.01; *** = P<0.001.

[3] Pasture intake calculated from n-alkane method.

Table 2-9 EXP2 (December) least squares means (±SE) for parameters of ingestive behaviour of autumn and spring calved cows offered generous herbage allowances.

Item	*Group*				
	Autumn	n	Spring	n	Significance
Daily intake (kg DM per cow)					
Pasture[3]	16.7 ± 0.58	82	16.4 ± 0.59	80	NS
Milk Production (cow/day)					
Kg MS (cow/day)	1.07 ± 0.03	82	1.30 ± 0.03	80	***
Liveweight (kg)	546 ± 9.5	40	481 ± 9.6	39	***
Grazing time (min/day)					
Day	454 ± 6.2	82	431 ± 6.3	81	*
Night	68 ± 4.6	82	90 ± 4.6	81	***
Total	521 ± 6.8	82	522 ± 6.9	81	NS
Ruminating time (min./day)					
Day	140 ± 6.5	82	159 ± 6.5	81	*
Night	306 ± 6.0	82	319 ± 6.0	81	NS
Total	446 ± 6.2	82	478 ± 6.2	81	***
Idling time (min./day)					
Day	85 ± 3.7	82	89 ± 3.7	81	NS
Night	155 ± 4.9	82	120 ± 4.9	81	***
Total	240 ± 6.0	82	209 ± 6.0	81	***
Biting rate (bites/min.)	51 ± 0.7	186	49 ± 0.7	208	*
Total bites (bites/day)	26062 ± 538.2	79	25597 ± 545.1	77	NS
Number of bites per					
kg of DM eaten	1648 ± 53.4	79	1661.8 ± 54.4	76	NS
kg of MS	23952 ± 677.8	75	19913 ± 673.4	76	***
Bite weight of pasture					
mg DM/bite	657 ± 24.89	79	666 ± 25.37	76	NS
mg DM/kg $LW^{0.75}$	5.2 ± 0.33	38	6.2 ± 0.33	38	*
Intake rate – pasture					
g DM/min.	32 ± 1.22	79	32 ± 1.24	76	NS
mg DM/kg $LW^{0.75}$/min.	258 ± 15.73	38	303 ± 15.73	38	*
Grazing time per kg DM eaten	33.1 ± 0.94	82	33.8 ± 0.95	80	NS

[1]Sunrise: September: 6 a.m. ; December: 5.45 a.m.

[1]Sunset: September: 6.20 p.m. ; December: 8.40 p.m.

[2]NS = not significant; † = P<0.1; * = P<0.05; ** = P< 0.01; *** = P<0.001.

[3] Pasture intake calculated from n-alkane method.

Discussion

Grazing behaviour

Approximately 59% (with 12-hours daylight per 24-hours) and 85% (with 15-hours daylight per 24-hours) of the grazing activity took place during daylight hours for EXP1 and EXP2 respectively, with distinctive peaks of grazing activity just after the morning and afternoon milkings. Cows preferred to graze during daylight hours if the conditions were agreeable, and feed was readily available. Grazing behaviour was similar between morning and afternoon milkings in EXP1 and EXP2. In both experiments, grazing activity declined after dusk, however in EXP1 dusk occurred 2-hours earlier, hence these cows required another grazing bout around 9-pm, whereas EXP2 cows had a larger grazing bout which lasted until dusk (9-pm), and did not actively graze again until 1am. In EXP1 and EXP2 the cows spent a consistent 47-50% of daylight hours grazing. Whatever remaining grazing time was required to satisfy their requirements then occurred during the night. In EXP1 this equated to 33% of night-time hours, whereas in EXP2, only 15% of night hours were spent grazing. This relationship is however dependent on the feed being readily available. In these experiments, cows were offered generous pasture allowances over the whole 24-hour period. The proportion of daylight hours spent grazing is less than the reported figure of 56% by Rook *et al.* (1994), but follows a similar pattern, with cows preferring to grazing during the day than at night as also reported by Penning *et al.* (1991b) with sheep, and Phillips and Leaver (1986b) with cows in early season. This pattern of preferred grazing during daylight hours was not found to be as strong by Garcia, J (1998) , where 74% of grazing activity occurred during 13-hours of daylight but only 68% for 15-hours of daylight.

Total grazing time (and hence herbage intake) is affected factors such as stage of lactation, liveweight, liveweight gain or loss and pregnancy state. Compared with S calving cows, the A calving cows spent less time grazing in EXP1 (571 *vs.* 609-minutes), but similar total time grazing in EXP2, (521 *vs.* 522-minutes). In EXP1 the A calving cows had lower herbage requirements than the S calving cows due to the S cows being at peak lactation (producing 0.4-kgMS more/cow/day), despite the A cows weighing 20-kg more. However in EXP2, the difference in MS production had dropped to 0.23-kg MS/cow/day difference, and the A cows weighed 65-kg more, in addition to being in the last trimester of pregnancy. Autumn calving cows did this by maintaining or increasing the proportion of daylight hours spent grazing, but decreasing their night grazing time. They grazed a similar amount to spring calving cows during the day in EXP1, but significantly less ($P<0.05$) during the night. In EXP2 the autumn calving cows grazed significantly more ($P>0.05$) during the day, and significantly less ($P<0.001$) during the night. For some reason, the spring calving cows did not have the same drive as the autumn calving cows to eat during daylight hours in EXP2, however they still spent 48% vs 16% of their day and night time grazing, respectively. These grazing times are typical of fully fed spring calving Holstein-Friesian cows and daylight hours at this time of the year, and fell within the range of other estimates reported in the literature (García-Muñiz 1998; Hodgson and Jamieson 1981; Phillips and Denne 1988; Phillips and Leaver 1986b; Gibb *et al.* 1997). Heifer grazing times and patterns were similar to mature cows in both experiments, despite a smaller herbage intake, which was significantly less ($P<0.01$) in December. Heifers may have been bullied during grazing, forcing them to graze less efficiently, or they may be less experienced grazers than mature cows, hence taking longer to eat, or they may be physically unable increase their herbage intake rate.

Cows in EXP1 ruminated for significantly less time (352 *vs.* 462-minutes), or 22 *vs.* 27-min/kgDM eaten than EXP2 respectively. Fibre composition (in the form of NDF or ADF) was higher in EXP2 than EXP1, possibly extending grazing time. This is consistent with the reported figures by Phillips and Leaver (1986a) of 28, 35 and 43 minutes in early, mid and late season respectively. Most of the ruminating was concentrated into the hours of darkness, but it was also interspersed between the major grazing bouts in the daylight. As the season advanced, there was less ruminating during daylight hours and more at night.

Bite characteristics

Cows in EXP1 showed significantly faster rates of biting, higher total number of daily bites and more bites per kg of DM eaten than in EXP2. Despite the faster bite rate, and because these bites weighed significantly less, cows in EXP1 had a slower intake rates, and hence had to graze longer per kg DM eaten. Heifers in EXP1 took significantly more bites per 24-hour period at a faster rate than mature cows, however this did not occur in EXP2. Both of the present experiments showed heifers took smaller bites, with their intake rate being less than mature cows, however intake rates per kg $lwt^{0.75}$ were similar. This is consistent with the finding of Phillips and Leaver (1986a). Heifers took more bites per kg of DM eaten and kg of MS produced. Garcia, J (1998) found cows which were genetically smaller had faster bite rates, lower bite weight, and selected swards of higher digestibility, possibly because due to their smaller mouth size they didn't graze down as far into the sward. Faster rates of biting and less mastication and rumination have been observed for lactating dairy cows grazing perennial ryegrass (*Lolium perenne*) white clover (*Trifolium repens*) swards, when they are forced to graze down to a sward surface height of 4 cm compared to 8 cm (Rook *et al.* 1994). This increase in biting rate is regarded as a compensatory mechanism triggered by a lower bite weight, and displayed in order to maintain total daily intake when sward conditions, especially height (Phillips 1993), or mouth size, i.e. a narrower incisor arcade breadth, (Illius and Gordon 1987) become limiting. Hodgson (1986) argues that variations in biting rate are better thought of as a direct response by the grazing animal to variations in sward conditions, rather than as an attempt to compensate for reduction in intake per bite. In the present experiments, the grazing conditions ensured both a high pre-grazing (2879-kg DM/ha ± 358) (EXP1), 3381-kg DM/ha ± 174 (EXP2) and a high post-grazing (1990-kg DM/ha ± 239) (EXP1), (2847-kg DM/ha ± 99) (EXP2) (mean ± SD) pasture covers. These sward conditions were unlikely to limit intake per bite and therefore trigger an increase in biting rate, grazing time and hence total number of bites (McGilloway and Mayne 1996). However, pre and post-grazing residuals were lower in EXP1, and heifers in EXP1 did increase their bite rate and total bites per day compared to mature cows, unlike in EXP2. This indicates that heifers are more sensitive to, and respond more readily to, sward conditions that may limit their intake.

Conclusions

Lactating dairy cows grazing behaviour remains consistent throughout the year, in that they prefer to grazing during daylight hours, but as they can only spend around 50% of the time grazing, they are always required to graze at night to some extent. Bite rate, bite weight, and intake rate are more related to sward characteristics than to stage of lactation. Mature cows are more readily able to increase their herbage intake rate under ideal conditions than heifers, and appear to substitute grazing time for an opportunity to increase herbage intake by maintaining grazing time. Heifers are not willing to graze longer than the mature cows (although theoretically able), to increase their total herbage intake.

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CHAPTER 3

The investigation of grazing and eating behaviour of cows consuming pasture and maze silage in a commercial farm.

Abstract

This experiment was carried out during winter 1998 at Number 1 Dairy Farm, Massey University, Palmerston North. The purpose was to measure the effect of offering supplements on the grazing behaviour of cows that had calved in the autumn. Fourteen experimental cows and their 48 herd mates were offered maize silage supplement (4-kg DM/cow daily) in bins after morning milking for approximately 2-hours, with 6 control cows non offered supplements (non-supplemented) being diverted directly to pasture. Pasture herbage intake by individual cows was measured using the alkane method as part of another experiment. These values were used in the present study to analyse the relationships between intake and grazing behaviour. Averaged across experiments, grazing time of the supplemented cows was shorter both during daylight (281 *vs.* 358-minutes; $P < 0.01$), and during the 24- hour day (546 *vs.* 615-minutes; $P < 0.05$) with a reduction of 24-min/kg supplement eaten. The supplemented cows had longer rumination times per 24-hour day (403 *vs.* 333-minutes; $P < 0.01$), in association with greater total DM intake (13.7 *vs.* 12.2-kg DM/day). Ruminating times/kg total DM intake was 27-min. (U) and 29-min. (S) with the majority of this rumination occurring at night. Differences between the groups in pasture herbage intake rate, bite rate, and total bites per day were not significant. Compared with the cows, heifers idled for longer during daylight, (46 *vs.* 40-minutes; $P < 0.01$), and had a greater number of bites per kg of DM eaten (3864 *vs.* 3001; $P < 0.05$). They also had a smaller bite weight (275 *vs.* 350-mg DM/bite; $P < 0.05$), but the difference was not significant when bite weight was expressed/kg lwt$^{0.75}$. The heifers also had a smaller herbage intake rate (16 *vs.* 22-g DM/min; $P < 0.01$), a difference which was significant when expressed per kg$^{0.75}$ of body weight (170 *vs.* 214 mg DM/kg LW$^{0.75}$; $P < 0.05$). The mature cows which were not offered supplement took a larger number of bites per day than those that were offered supplements (40074 *vs.* 33284), whereas for the heifers, the difference was much smaller with 34527 *vs.* 33007 bites per day for the non-supplemented and supplemented heifers respectively. Under the conditions of the present experiment, supplementation was associated with differences in the pattern of grazing behaviour of lactating cows, but had no effect on bite mechanics or intake rate. The mature cows showed larger changes in grazing time to the consumption of supplements, than the heifers.

Introduction

Milk production in New Zealand is based on a seasonal system of reproduction that closely matches the requirements of lactating and growing cattle fed solely on grazed pasture with the seasonal supply of grass. However at some stages of the season, cows are constrained by the availability of feed especially at high stocking rates (Bryant 1990). To remove this constraint maize silage is being used increasingly as a source of additional feed, for example in summer and autumn (late lactation) in the traditional spring calving system, and over the winter in herds, which produce milk at this time of year.

A major factor limiting the herbage DM intake of the grazing dairy cow is its ability or willingness to consume sufficient herbage within the time available at pasture. Supplementary feeds are offered to grazing animals to maintain or increase total daily intakes and animal performance, despite a limited supply of pasture. Conserved forage is a useful supplement to pasture for grazing dairy cows, since cows tend to eat it only when fresh herbage is in short supply (Phillips and Leaver 1985b, Phillips and Leaver 1985a).

Phillips and Hecheimi (1989) found an interaction between the effect of herbage height and of supplementation on grazing time, with the effect being more pronounced at low herbage availability. This does not necessarily conflict with previous research which found that substitution rate (change in kg herbage DM eaten per kg forage DM supplement eaten) is greater at high herbage availability. Phillips and Leaver (1985b) reported substitution rates of 1.29-kg herbage DM/kg grass silage DM at a herbage height of 9.6 cm in early summer, and of 0.68-kg herbage DM/kg grass silage DM at a herbage height of 7.2-cm in late summer. This is because the rate of DM intake is also greater at high herbage availability and hence the effect of supplement on grazing time is smaller (Phillips and Hecheimi; 1989). If sward conditions are not limiting, forage supplements produce greater substitution rates than concentrate supplements, and therefore are most suitable when herbage allowances are low. In a short term indoor feeding experiment with irrigated perennial pasture as the base feed, marginal returns to feeding maize silage averaged 0.9 and 0.6-kg milk/kg DM in early and late lactation, respectively (Stockdale 1995). These responses were obtained from feeding up to 5-kg DM/cow/day of maize silage to cows eating about 7 kg DM/cow/day of pasture. When cows consumed more pasture (9 to 12-kg DM/cow/day) in early lactation, marginal returns declined, from 0.9 to 0.7-kg milk/kg of extra maize silage DM eaten (Stockdale 1995).

Phillips and Leaver (1986b) investigated the effects of offering supplementary forage on the grazing behaviour of dairy cows in a series of experiments. Grazing time was reduced by 37 and 30 min/kg forage DM eaten in early and late season respectively. Grazing time was reduced by 3 to 20-min/kg concentrate DM eaten depending on sward conditions (Sarker and Holmes 1974, Jennings and Holmes 1984). The bite size and rate of herbage DM intake were reduced for cows eating large quantities of silage, but the rate of biting was not affected, and rumination time was increased for cows offered silage (Phillips and Leaver 1986b, Phillips and Hecheimi 1989), particularly when the silage was eaten in large quantities, and probably reflects the increased intake of fibrous material (Hancock 1954). Effects on milk fat yield were largest when conserved forage was offered (1) to high-yielding cows, (2) with a restricted availability of grazed herbage, and (3) in autumn (Phillips and Leaver 1985b, Phillips and Leaver 1985a). An advantage of forage feeding is that the rate of intake is higher.

Phillips and Hecheimi (1989) investigated the effect of season of year on the ingestive behaviour of dairy cattle. In experiment 1, when daylength averaged 16.3-h (early season), the change in grazing time caused by offering supplementary feed was effected by a reduction in the number of grazing bouts. Phillips and Leaver (1986a) also found that cows consumption of supplementary silage replaced one grazing bout. In experiment 2, when daylength averaged 12.8-h, the number of bouts at low herbage height tended to be reduced when no silage was fed, because the bouts were merged together and bout duration was increased.

This chapter reports the results of an experiment (EXP3) carried out with autumn-calved cows in early lactation, in June (winter) 1998, which was intended to measure the effect of offering supplements, maize silage on their grazing behaviour.

Materials and Methods

Animals

Twenty lactating autumn (A) calving Holstein-Friesian cows from the Number 1 Dairy Farm, Massey University herd, were used in one short-term grazing experiment in the winter (June) of 1998 (EXP3). Details on the formation of these lines have been given by Garcia *et al.* (1998) and in Chapter 2. Twelve cows (4 primiparous and 8 multiparous) were selected from the herd and blocked into pairs according to level of milk yield, days since calving and lactation number. Cows within each block were randomly assigned to one of two treatments: supplemented with maize silage or cows not receiving supplements (non-supplemented). Another 8 cows were randomly selected from the rest of the herd and allocated to the supplement group in order to increase the number of individual estimates of pasture and maize silage intakes (Table 3-1).

Table 3-1 Age composition of cows used in EXP3.

	Supplement		
	Yes	No	Total
Heifers	4	2	6
Cows	10	4	14
Total per treatment	14	6	20

Grazing Management

Cows were offered their herbage allowance for 2-days as a new paddock after the morning milking at the beginning of each measurement period. The cows were grazed as a single group with their herd mates, using temporary electric fences to provide an area sufficient for an average daily herbage allowance of 28.9 ± 2.5-kg DM per cow for two days as assessed by a rising platemeter (Ashgrove Pastoral Products, Palmerston North, New Zealand). Fourteen experimental cows and their herd mates were offered maize silage supplement (4-kg DM/cow daily) in bins (1.5-linear m per cow) after morning milking for approximately 2-hours, with 6 non-supplemented control cows being diverted directly to pasture instead of the supplement.

Pastures

Predominately perennial ryegrass-white clover pastures (comprising more than 70% of the herbage dry matter) were grazed. The group's level of feeding was estimated indirectly by measuring pre and post-grazing herbage masses from 100 readings of pasture height using a rising plate meter (RPM) (Michell 1982), and the area allocated daily for grazing. Daily herbage allowance was calculated from the expression given by Milligan *et al.* (1987) as:

$$\text{Herbage allowance (kg DM/cow/day)} = \frac{\text{Pregrazing pasture mass (kg DM/ha)} \times \text{Area grazed per 24 hours}}{\text{Number of cows}} \quad [3.1]$$

The RPM was calibrated monthly from July 1998 to February 1999, with the results present in Chapter 4. These calibrations did not cover the period of this experiment, so the equation Massey uses on a regular basis on the Number 1 dairy farm has been used instead. Pre-grazing and post-grazing pasture masses (kg DM/ha) were estimated using the equation y =158x + 200; where x is the value measured by the rising plate meter.

Grazing behaviour

Grazing behaviour on pasture was monitored during two separate periods, each of 24-hours, with one period in each 5-day sub-period during the 10-day period when intakes by individual cows were measured using the alkane technique (Mayes *et al.* 1986). Observers were trained prior to the recording of the information, and allocated working shifts of no more than three hours to avoid fatigue. Nocturnal observations were aided by using a spotlight, and by painting the cow's identification number on the flanks and rumps using fluorescent or enamel paint. The animals were accustomed to the presence of observers, and only minor disturbances in their pattern of grazing behaviour were expected and observed. Grazing, ruminating, and idling times were estimated by recording the grazing activity of individual cows every ten minutes during for the 24-hour period (Hodgson 1982). Animals were considered to be grazing when their heads were down to the ground, and they were biting, searching or chewing (Cazcarra and Petit 1995). Grazing activities were recorded by letter (Inwood *et al.* 1992) using the recording sheet shown in Appendix 3.1.

During the period of faeces collection, biting rate was also measured on all cows. Biting rates were recorded three times per day at peak grazing hours after morning milking (8:00-9:00 a.m.), at noon (12:00-13:00 p.m.), and after afternoon milking (16:00 -17:00

p.m.). Within each one-hour observational period, two consecutive records of biting rate were obtained from each cow by counting the time for 20 bites to be taken (Jamieson and Hodgson 1979). Grazing bite rates (number of bites/min) for each hour of the day were calculated for each cow by averaging the two consecutive records. Sound and movement of the head defined a grazing bite.

Maize Silage consumption behaviour

Close observation of the cows at the feeding bin was expected to disturb their natural behaviour, therefore a video camera was used to record their behaviour. This was mounted on a stand so as to provide minimum disturbance to the eating cows. Recording started when cows entered the feed pad, and was stopped when the last cow left. The video recorder was able to distinguish cows that were eating from those that were not eating.

Measurements recorded

Live weight, condition score

On one day per month, cows were weighed after the afternoon milking using electronic scales (Tru Test, NZ Ltd) and their body condition was assessed visually, on a scale 1 (thin) to 9 (fat) (Holmes and Wilson 1987).

Yield of milk and milk components

Cows were milked twice daily at approximately 06.00 and 15.00-h. On one day during the two-week trial period, aliquots of milk samples were collected from each cow on two consecutive milkings, and the samples were weighed to measure milk yield, and analysed to measure the concentration of fat, protein, and somatic cells.

Herbage intake and digestibility

These are part of another study by Sergio Garcia, Agricultural Services, Massey University. Only the main results will be published here, and discussed in relation to grazing behaviour.

Fifteen closure cages (1-m × 0.5-m × 0.5-m) were distributed on each paddock before grazing, after grazing approximately 30 sub-samples were taken by 'hand-plucking' from each cage to simulate the height of grazing, in order to accurately represent the actual grazed material. The pasture samples were first pooled by paddock and then by sampling period, resulting eventually in two composite samples being chemically analysed (one for each 5-day period of faecal collection).

The total weight of maize silage fed was weighed daily (on a wet basis) using the load-cells of the forage-wagon. Samples of silage were taken daily from the bins, oven-dried at 60°C for 48-h and the % of DM (and total actual DM offered) was calculated of each experimental day. All sub samples were later pooled into one sample for each 5-day period. Uneaten silage was estimated by collecting and weighing the entire accumulated residue at the end of each 5 day sampling period. A sample of the residual was taken and oven dried (60°C, 48-h) to calculate the % DM. The average consumption of maize silage by the whole herd was calculated as the difference between the total amounts of DM offered and refused during each period.

On day 6, twenty cows were dosed with a controlled release device capsule containing 8 g of dotriacontane (C_{32}) and 8-g of hexatriacontane (C_{36}) (Captec™, New Zealand) with a constant release rate for each n-alkane of approximately 400 mg per day. Faecal samples were taken twice daily (0930-h and 1300-h) from each individual cow from the ground during two 5-day periods (days 13 to 18 and 20 to 25). A composite sample was created by adding (wet basis) a new sub sample to a pool (one per cow and per period) immediately after taking the samples. Thus two composite samples (each containing morning and afternoon sub-samples of 5 consecutive days) were analysed for each individual cow.

Faecal, pasture, and maize silage composite samples were thawed, freeze-dried, and ground in a mill (1-mm screen). Intakes of pasture DM were estimated by the n-alkanes method (Dove and Mayes 1991) which includes the amount of supplement consumption. Tritiacontane (C_{33}) was used as the naturally occurring alkane and C_{32} as the dosed alkane. The proportion of faecal DM from each feed source was estimated by the $\delta^{13}C$ method (Jones *et al.* 1979). Intake estimates, together with the *in vitro* organic matter digestibility of each feed source, were combined in an iterative process in which values for DM intake of pasture and maize silage corrected each other until further corrections resulted in no further changes of intake <0.001-kg (Garcia *et al.* 1999).

Pasture and maize silage samples were also analysed for organic matter (OM), neutral detergent fibre (Roberston and Van Soest 1981), *in vitro* digestibility of DM and OM (Roughan and Holland 1977) and nitrogen by Kjeldahl procedure.

Derived variables

The above measurements of grazing behaviour and herbage intake by individual animals were used to calculate the following variables (Gong *et al.* 1996, García-Muñiz 1998).

$$\text{Biting rate (bites/min)} = \frac{\text{20 bites}}{\text{time spent to take 20 bites (sec)}} \times 60 \qquad [3.2]$$

$$\text{Bite weight (mg DM/bite)} = \frac{\text{dry matter intake (kg/day)}}{\text{biting rate (bites/min)} \times \text{grazing time (min/day)}} \times 1000{,}000 \qquad [3.3]$$

$$\text{Relative bite weight (mg DM/bite per kg LW)} = \frac{\text{bite weight}}{\text{LW (kg)}} \qquad [3.4]$$

Rate of intake (mg DM/min) = bite weight × biting rate [3.5]

Statistical Analysis

Data was analysed using PROC GLM (SAS Institute 1990). Data for LW, milksolids yield, DM intake, and the parameters of grazing behaviour (grazing time, ruminating time, idling time, biting rate, total bites per day, bite weight and rate of intake) were analysed using Least Squares Means for effect of age and supplement. Interactions between supplement and age of cow were analysed.

Results

Sward and supplement variables

The average sward conditions during EXP3 and the results of the chemical analysis of the pasture are summarised in Table 3-2. No statistical analysis was performed on these variables, as they were repeated measures obtained from the two groups managed as a single group. Results are summarised as means and standard deviations for the sward variables and nutritive value of the feeds. Figure 3-1 also shows the average sward heights recorded during the course of EXP3.

Table 3-2 Means and standard deviations for pasture variables recorded during EXP3

Variable	*EXP3*
PASTURE	
Herbage mass (kgDM/ha)	
Pre-grazing	2758 ± 430
Post-grazing	1760 ± 387
Daily herbage allowance	
kg DM/cow	63.2 ± 11.3
Herbage disappearance rate (apparent intake) (kg/cow/day)	13.4 ± 3.9
PASTURE	
Dry matter (%)	14.0 ± 0.5
Organic matter (g/100 g DM)	88.4 ± 0.4
In vitro Organic matter digestibility (g/100 g DM)	74.1 ± 1.2
Neutral Detergent Fibre (g/100 g DM)	39.8 ± 0.7
Crude protein (g/100 g DM)	26.3 ± 2.1
MAIZE SILAGE	
Dry matter (%)	30.1 ± 0.1
Organic matter (g/100 g DM)	94.3± 0.1
In vitro organic matter digestibility (g/100 g DM)	65.4 ± 0.6
Neutral Detergent Fibre (g/100 g DM)	48.6 ± 0.4
Crude protein (g/100 g DM)	7.2 ± 0.2

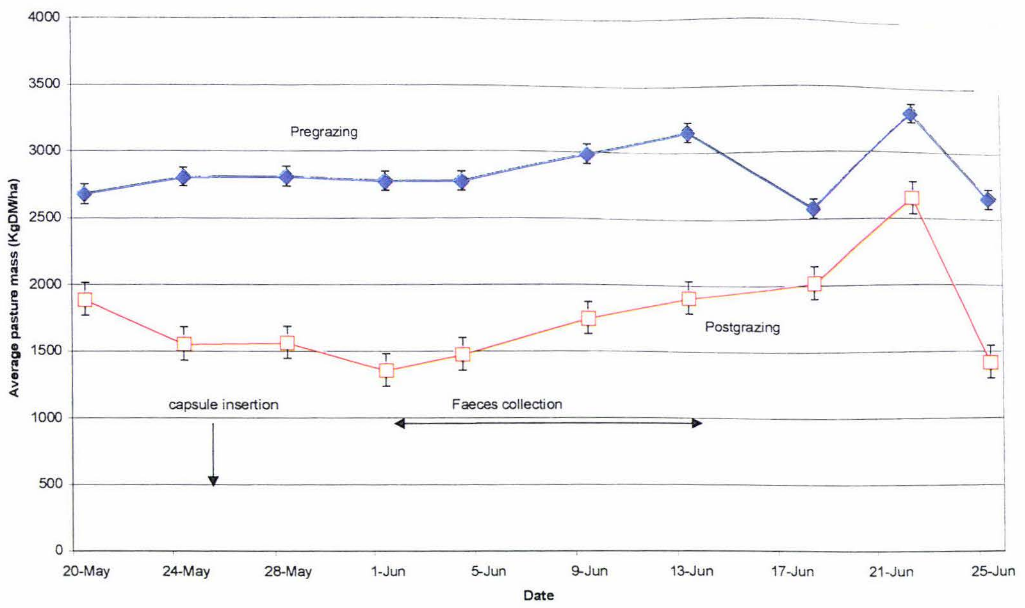

Figure 3-1 Means (±SE) for pre-grazing (♦) and post-grazing (□) herbage masses estimated by the rising plate meter during EXP3

Average values for the whole herd

The average milk production for this period is shown in Table 3-3. Pasture intake by the herd was calculated from the difference between herbage mass present before and after grazing as assessed by the rising plate meter. The whole herds mean silage intake was calculated from the difference between silage DM offered and refused (Table 3-3)

Table 3-3 Means and SD for intake and production for the whole Holstein-Friesian autumn calving herd offered generous herbage allowances during early-mid lactation (June).

Daily Intake (kg DM per cow)	Whole herd Mean ± SD
Pasture	13.2 ± 0.49[1]
Maize Silage	3.8 ± 0.25[2]
Total intake	17.0 ± 0.45
Milk Solids Yield	1.44 ± 0.38

[1] Calculated from the difference between herbage mass present before and after grazing.
[2] Calculated from the difference between silage DM offered and refused.

Observation of Maize silage intake

The supplemented cows entered the feedpad where the maize silage was being fed before it was light enough for the camera to distinguish cows. Once light, the Velcro's collars and paint markings were still difficult to observe in the confined feeding space. Hence no useful results were obtained on the feeding behaviour of the cows while eating the maize silage.

Ingestive behaviour and intakes by individual cows

The supplemented cows ate on average 2.9-kg DM of maize silage per day. For mature cows, pasture intakes were similar ($P = 0.17$) for the supplemented (10.8-kg DM/cow/day) and the non-supplemented cows (12.1-kg DM/cow/day) (Table 3-4). Heifer (H) intakes were significantly less than mature cow (M) intakes at 8.9 (H) *vs.* 12.2-kg DM, (M) ($P<0.001$) from pasture, and 1.2-kg DM (H) *vs.* 2.5-kg DM (M) ($P<0.05$) from maize silage (Table 3-5).

Least squares means for parameters of grazing behaviour are summarised in Table 3-4, Table 3-5, and Table 3-6. The distribution of grazing time during the 24-hour periods of recordings is given in Figure 3-2. Cows that were non-supplemented (U) spent significantly longer gazing during daylight and during the 24-hour day and less time ruminating (Table 3-4). Overall, about 51% and 58% of the grazing activity was carried out during the hours of daylight for supplemented (S) and non-supplemented (U) cows, respectively. Similarly S and U cows carried out about 75% and 82% of rumination during the night, respectively. Grazing activity peaked after the morning and afternoon milking, with smaller peaks at 8pm and midnight (Figure 3-2). First calving 2-year old heifers had slower bite rates, ($P<0.05$), smaller bites ($P<0.05$) with more bites per kg DM eaten ($P<0.05$) than mature cows, and also had a slower intake rate per min ($P<0.01$)(Table 3-5). The difference in bite weight between heifers and mature cows was removed when intake was expressed per kg or per $kg^{0.75}$.

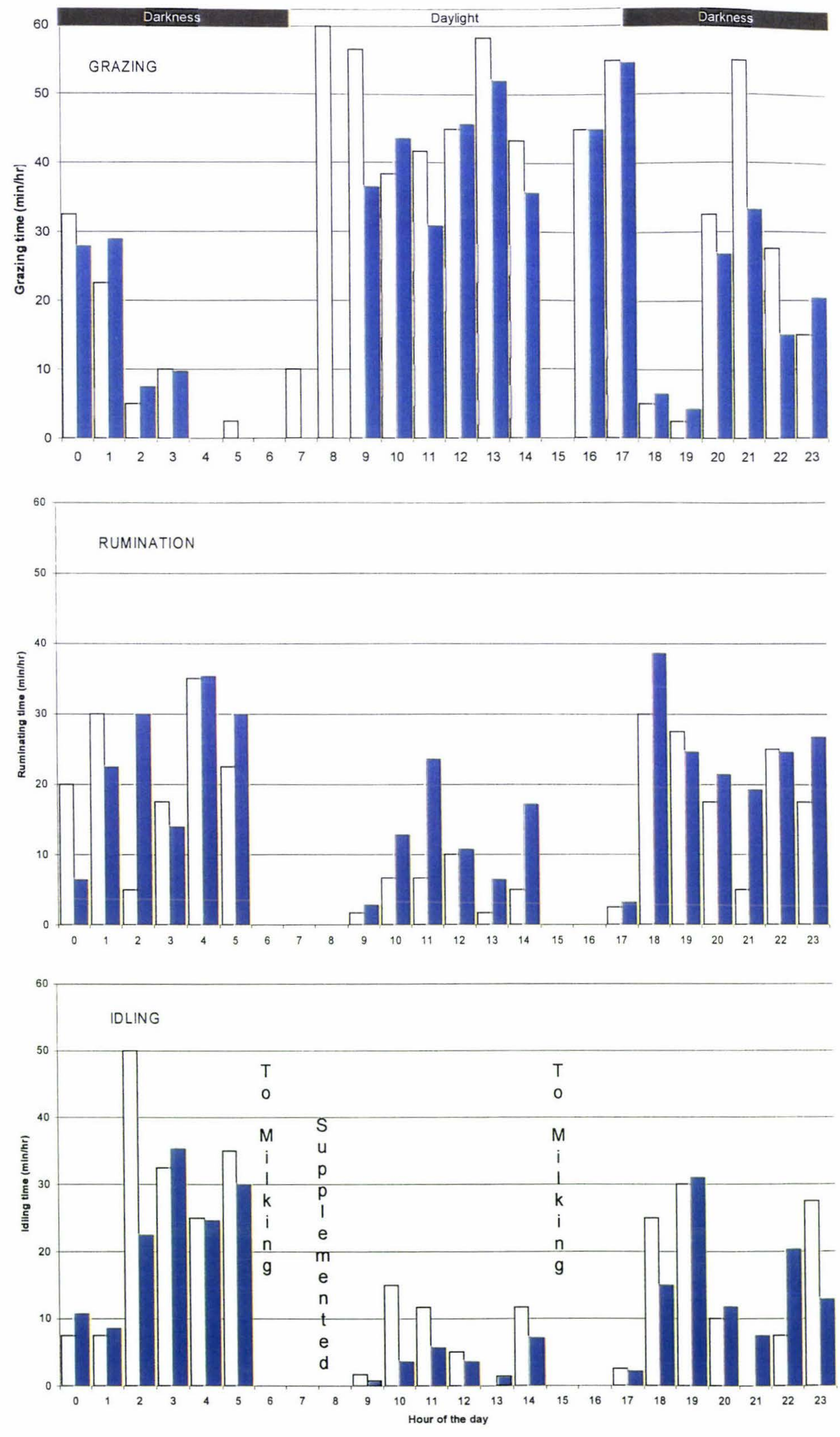

Figure 3-2 Grazing, ruminating and idling times during each hour of a 24-hour observational period for supplemented (■) or non-supplemented (□) cows grazing generous herbage allowances.

Table 3-4 Least squares means (±SE) for parameters of ingestive behaviour of supplemented and non-supplemented autumn calved cows offered generous herbage allowances .

item[1]	Group		Significance[2]
	Supplemented n = 28	Non-supplemented n = 12	
Daily intake (kg DM per cow)			
Pasture[3]	10.8 ± 0.52	12.1 ± 0.79	0.17
Maize[3]	2.9 ± 0.18	0.0 ± 0.28	***
Total	13.7 ± 0.58	12.2 ± 0.88	0.14
Milk Production (cow/day)			
Kg MS	1.46 ± 0.06	1.47 ± 0.09	NS
Grazing time (min/day)			
Day	281 ± 13.1	358 ± 19.2	**
Night	264 ± 16.0	257 ± 23.5	NS
Total	546 ± 16.9	615 ± 24.7	*
Ruminating time (min./day)			
Day	94 ± 8.1	61 ± 11.9	*
Night	310 ± 9.1	273 ± 13.3	*
Total	403 ± 12.0	333 ± 17.6	**
Idling time (min./day)			
Day	38 ± 5.4	39 ± 7.9	NS
Night	183 ± 15.1	228 ± 22.1	NS
Total	221 ± 15.6	267 ± 22.9	NS
Biting rate (bites/min.)	61 ± 1.1 [4]	59 ± 1.7 [5]	NS
Total bites (bites/day)	33905 ± 1211.4	36540 ± 1773.3	NS
Number of bites per kg of DM eaten	3596 ± 192.5	3269 ± 281.8	NS
Bite weight of pasture			
mg DM/bite	309 ± 17.28	316 ± 25.29	NS
mg DM/kg $LW^{0.75}$	3.1 ± 0.16	3.2 ± 0.24	NS
Intake rate – pasture			
g DM/min.	19 ± 1.04	19 ± 1.52	NS
mg DM/kg $LW^{0.75}$/min.	194 ± 9.65	190 ± 14.13	NS

[1] Sunrise: 7.00a.m.; Sunset: 5.30p.m.

[2] NS = not significant; † = $P < 0.1$; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

[3] Pasture intake of S and NS calculated from n-alkane method; Maize Silage intake from a combination of alkanes and δ13 method.

[4] Number of observations = 42.

[5] Number of observations = 18.

Table 3-5 Least squares means (±SE) for ingestive behaviour parameters of autumn calved supplemented and non-supplemented cows and heifers offered generous herbage allowances.

item[1]	*Group*		Significance[2]
	Heifer n = 12	Mature cow n = 28	
Daily intake (kg DM per cow)			
Pasture[3]	8.9 ± 0.67	12.2 ± 0.44	***
Maize[3]	1.2 ± 0.45	2.46 ± 0.29	*
Total	10.1 ± 0.66	14.6 ± 0.43	***
Physical Data			
Kg MS (cow/day)	1.33 ± 0.09	1.52 ± 0.06	†
Liveweight (kg)	424 ± 10.0	481 ± 6.5	***
Grazing time (min/day)			
Day	314 ± 19.2	325 ± 13.1	NS
Night	266 ± 23.4	255 ± 16.0	NS
Total	581 ± 24.7	580 ± 16.9	NS
Ruminating time (min./day)			
Day	74 ± 11.9	80 ± 8.1	NS
Night	299 ± 13.3	283 ± 9.1	NS
Total	373 ± 17.6	363 ± 12.0	NS
Idling time (min./day)			
Day	46 ± 7.9	30 ± 5.3	†
Night	192 ± 22.1	219 ± 15.1	NS
Total	238 ± 22.9	248 ± 15.6	NS
Biting rate (bites/min.)	58 ± 1.7[4]	62 ± 1.1[5]	*
Total bites (bites/day)	33767 ± 1773.3	36679 ± 1211.4	NS
Number of bites per kg of DM eaten	3864 ± 281.8	3001 ± 192.5	*
Bite weight of pasture			
mg DM/bite	275 ± 25.29	350 ± 17.28	*
mg DM/kg $LW^{0.75}$	3.0 ± 0.24	3.4 ± 0.16	NS
Intake rate			
g DM/min.	16 ± 1.52	22 ± 1.04	**
mg DM/kg $LW^{0.75}$/min.	170 ± 14.13	214 ± 9.65	*

[1] Sunrise: 7.00a.m.; Sunset: 5.30p.m.

[2] NS = not significant; † = P < 0.1; * = P < 0.05; ** = P < 0.01; *** = P < 0.001

[3] Pasture intake of S and NS calculated from n-alkane method; Maize Silage intake from a combination of alkanes and δ13 method.

[4] Number of observations = 18.

[5] Number of observations = 42.

Table 3-6 Least squares means (±SE) for ingestive behaviour parameters of supplemented and non-supplemented autumn calved Holstein-Friesian cows and heifers offered generous herbage allowances during early-mid lactation. Means within rows with differing letters are significantly different (P<0.05).

item[1]	*Group*			
	Heifer No Supplement n = 4	Heifer Supplement n = 8	Mature No Supplement n = 8	Mature Supplement n = 20
Intake				
Pasture[2]	9.4 ± 1.14^{ac}	8.6 ± 0.81^{a}	13.5 ± 0.81^{b}	11.7 ± 0.51^{bc}
Maize[2]	0.0 ± 0.36^{a}	1.7 ± 0.26^{b}	0.08 ± 0.26^{a}	3.4 ± 0.16^{c}
Total	9.4 ± 1.12^{a}	10.4 ± 0.79^{a}	13.5 ± 0.79^{b}	15.1 ± 0.5^{b}
Milk Prodn (cow/day)				
Kg MS	1.2 ± 0.16^{a}	1.4 ± 0.11^{a}	1.6 ± 0.11^{a}	1.5 ± 0.07^{a}
Grazing time (min/day)				
Day	353 ± 31.4 ^{ab}	276 ± 22.2 ^{a}	364 ± 22.2 ^{b}	286 ± 14.0^{a}
Night	251 ± 38.3 ^{a}	281 ± 27.1 ^{a}	263 ± 27.1 ^{a}	248 ± 17.2 ^{a}
Total	604 ± 40.3 ^{ab}	558 ± 28.5 ^{ab}	626 ± 28.5 ^{a}	534 ± 18.0 ^{b}
Ruminating time (min./day)				
Day	63 ± 19.5 ^{ab}	86 ± 13.8 ^{ab}	59 ± 13.8 ^{a}	102 ± 8.7 ^{b}
Night	281 ± 21.7 ^{ab}	317 ± 15.3 ^{a}	264 ± 15.3 ^{b}	302 ± 9.7 ^{a}
Total	344 ± 28.7 ^{ab}	403 ± 20.3 ^{a}	323 ± 20.3 ^{b}	404 ± 12.9 ^{a}
Idling time (min./day)				
Day	43 ± 12.8 ^{ab}	50 ± 9.1 ^{a}	35 ± 8.1 ^{ab}	25 ± 5.7 ^{b}
Night	225 ± 36.1 ^{a}	159 ± 25.5 ^{a}	231 ± 25.5 ^{a}	207 ± 16.2 ^{a}
Total	268 ± 37.3 ^{a}	209 ± 26.4 ^{a}	266 ± 26.4 ^{a}	232 ± 16.7 ^{a}
Biting rate (bites/min.)[3]	55 ± 2.7 ^{a}	60 ± 1.9 ^{b}	63 ± 1.9 ^{ab}	61 ± 1.2 ^{ab}
Total bites (bites/day)	33007 ± 2895.8 ^{ab}	34527 ± 2047.7 ^{ab}	40074 ± 2047.7 ^{a}	33284 ± 1295.1 ^{b}
Number of bites per				
kg of DM eaten	3549 ± 460.2 ^{ab}	4179 ± 325.4 ^{b}	2989 ± 325.4 ^{a}	3013 ± 205.8 ^{a}
Bite weight of pasture				
mg DM/bite	288 ± 41.30 ^{ab}	262 ± 29.21 ^{a}	344 ± 29.21^{ab}	356 ± 18.47 ^{b}
mg DM/kg $LW^{0.75}$	3.1 ± 0.39 ^{a}	2.8 ± 0.28 ^{a}	3.3 ± 0.28 ^{a}	3.5 ± 0.18 ^{a}
Intake rate				
g DM/min.	16 ± 2.49 ^{a}	16 ± 1.76 ^{a}	22 ± 1.76 ^{b}	22 ± 1.11 ^{b}
mg DM/kg $LW^{0.75}$/min.	169 ± 23.08 ^{ab}	172 ± 16.32 ^{a}	211 ± 16.32 ^{ab}	216 ± 10.32 ^{b}

[1] Sunrise: 7.00a.m.; Sunset: 5.30p.m.

[2] Pasture intake of S and NS calculated from n-alkane method; Maize Silage intake from a combination of alkanes and δ13 method.

[3] For Biting Rate: Heifer (no supplementation) n = 6; Heifer (supplemented) n = 12; Mature (no supplementation) n = 12; Mature (supplemented) n = 30

Discussion

Percentage of total time spent grazing

About 51% and 58% respectively of grazing activity by the supplemented and non-supplemented cows took place during the 10.5-daylight hours, with distinctive peaks of grazing activity just after the morning and afternoon milkings, and a long evening grazing bout around 8-pm. The supplemented cows would be expected to graze less, considering their intake of maize silage. The proportion of total grazing time spent grazing during daylight hours is significantly less than the reported figure of 88% by Rook *et al.* (1994), however this was measured with 17-hours of daylight. Phillips and Leaver (1986a) analysed diurnal variation in behaviour, and showed that the reduction of daylength in the autumn caused a compression of grazing time to mainly within daylight hours, with more ruminating at night. However the ability of cows to accommodate reduced daylength depends on their feed requirements (e.g. due to stage of lactation) and enforced time out of the paddock due to milking, with up to an hour walk either way to the milking shed common in New Zealand. The values of 51% and 58% were significantly greater than the expected value of 44% if the total grazing time had been uniformly distributed over a 24-hour day. Approximately 45% and 57% of the available daylight was spent grazing for the supplemented and non-supplemented cows respectively. This is consistent with the 56% found by Rook *et al.* (1994), supporting the conclusion that dairy cows graze more during darkness as daylength declines.

Rook *et al.* (1994) suggested that the occurrence of greater grazing activity during the morning and afternoon, immediately after milking, could be the result of a short-term fasting effect at milking. Phillips and Leaver (1986a) suggested that as daylight hours decreased, grazing time before morning milking decreased and was compensated by a midnight meal. Certainly the observed grazing behaviour in this trial agrees with this view, with little or no grazing occurring before morning milking during the winter of this trial, with large peaks of grazing around midnight and after the morning and afternoon milkings. Cows are often offered access to fresh pasture after milkings, and this may reinforce the behaviour of not grazing just before milking in anticipation of the fresh pasture being provided after milking. On average the cows in this trial received access to new pasture every two days, however this did not stop them from anticipating fresh pasture on a more regular basis. If the cows thought they were going back to the same paddock after milking (i.e. after milking being sent back down the same race which they came from before milking), it took longer for them to reach the paddock, as they walked slower, and took frequent stops.

Total grazing time

With generous feeding (average pasture allowance 63-kg DM/cow/day, and post-grazing residual 1760-kg DM/ha), the non-supplemented cows spent a total of 615-min. grazing, with this decreasing to 546-min. for the supplemented cows. Similar results were found by Rook *et al.* (1994) of 656 and 623-min. on 60 and 80-mm swards respectively with non-supplemented cows, and 552-min. for supplemented cows. Garcia, J (1998) reported grazing times of spring calved cows during early-mid lactation (daylight hours 13 to 15-hours) of between 498 and 516-min. Phillips and Leaver (1986a) found that dairy cows spent 360-540-min./day grazing and suggested that these represent maximum grazing times for dairy cows in general. However this is not shown in the current work, or that of *Rook et al.* (1994).

Effect of supplements

The supplemented cows had longer rumination times than the non-supplemented cows (403-minutes *vs.*. 333-minutes), due to their increased total DM intake, and probably also affected by maize silage's higher fibre content (49 *vs.* 40-g/100 g DM) and decreased digestibility (65 *vs.* 74 -g/ 100 g DM), when compared to pasture. Phillips and Leaver (1986a) found rumination times/kg herbage DM intake in early, mid and late season were 28, 35, and 43-minutes respectively. These results agree with the present results of 27 (non-supplemented) and 29-minutes per kg herbage DM in total DM (supplemented) cows during early lactation. Rumination was concentrated mainly into the hours of darkness for both groups of cows, with 61 *vs.* 273-minutes of ruminating during daylight and night respectively for the non-supplemented animals and 94 *vs.* 310-minutes ($P<0.05$) with the supplemented cows. The supplemented cows appeared to substitute ruminating for idling during the night.

Feeding maize silage reduced grazing time during daylight by the supplemented cows (281 *vs.* 358-min.; $P < 0.01$) by the supplemented and non-supplemented cows respectively), with supplemented cows substituting rumination for grazing, but with similar idling times (38 *vs.* 39-minutes) during daylight. The supplemented and non-supplemented cows had similar grazing times at night. Reductions in grazing time averaged 26-min./kg supplement eaten, which is similar to the values of 37 and 30-min/kg reported by Phillips and Leaver (1986b). Grazing characteristics such as bite size, bite rate and intake rate were not affected significantly by offering maize supplements with an average intake of 2.9-kg DM Maize Silage/cow/day. The total number of daily grazing bites (33905 (supplemented) *vs.* 36540 (non-supplemented)) was reduced, but not significantly by consumption of supplementary forage, despite the reduced grazing times. The non-supplemented cows tended to take slower larger bites, at a slower bite rate, resulting in similar intake rates.

Comparison between heifer and mature cows

Herbage intake per cow was higher for mature cows as would be expected from their heavier liveweight and higher yield of milksolids, however there was no significant difference in grazing or ruminating times. Cows are social grazers, which might explain why the heifers grazed for the same time as mature cows. Alternatively the heifers may have been bullied, and therefore taken longer to eat because the mature cows were always moving them on from where they were eating. Therefore over the same grazing time, heifers took smaller bites (due to smaller body size) at a slower rate because of disruptions by the mature cows with fewer total bites and more bites taken per kg DM eaten. There was an interaction between supplementation and maturity of the cow. For the mature cows, those which were not offered supplement increased their total bites per day by 6790 bites compared those which were offered supplements, whereas for heifers those which were not offered supplements took only 1520 more bites than those which were not offered supplement. This suggests that mature cows may have a greater drive for food, or that heifers are limited in their ability to increase grazing time and total number of bites, by physical or social factors.

Conclusions

Non-supplemented grazing cows in early lactation grazed for an hour longer than supplemented cows, yet did not obtain the same total intake, suggesting that voluntary feed intake is increased when supplemented are provided, with 10.25 hours being close to the maximum grazing time possible for lactating cows. Bite size, bite rate, and pasture intake rates were not affected by offering maize supplements with an average intake of 2.9-kg DM Maize Silage/cow/day. Intake rate (g DM/min. grazing time) for heifers and cows was not affected by supplementation, with the heifers having a consistently lower intake rate when grazing. The lower pasture intake rate of heifers may be due to them being physically unable to eat any more DM/min., or it may be due to social facts such as bullying, where mature cows harass heifers, forcing them to continuously move and hence not graze as efficiently.

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CHAPTER 4

Calibrations of the Rising Plate Meter; Effects of season and irrigation

Abstract

The purpose of this experiment was to derive calibration equations for the Rising Plate Meter (RPM) on Massey Number One Dairy farm, which would measure any differences between seasons, irrigated and non-irrigated pastures, and between the three farming systems. From mid-July 1998 to mid-December inclusive, monthly plate meter calibration cuts were taken in the early afternoon at Massey University Number 1 dairy unit, with 54 quadrats cuts (27 pre-grazing and 27 post-grazing), from 6 separate paddocks on each of the 6 occasions. Monthly samples were divided evenly between the three farmlets, which were run separately on this farm (100% Autumn calving (Green), 100% Spring calving (Pink), and 50:50 autumn/spring calving (Red)). In early February, 54 quadrats were also cut from irrigated and non-irrigated pastures. The effects of farmlet, pre or post-grazing samples, and irrigated or non-irrigated pastures on the regression equations were not significant. However the differences between months were significant ($P < 0.05$). The monthly regression equations were; $y = 77x + 1420$ (July); $y = 104x + 673$ (August); $y = 124x + 821$ (September); $y = 66x + 1567$ (October); $y = 92x + 1289$ (November); $y = 85x + 1959$ (December); $y = 148x + 1308$ (February) where y = herbage yield (kg DM/ha) and x = rising plate reading (cm). These were compared to recently published equations, all of which gave similar values in February, but not in October. The regression coefficient was important for accurate estimation of pasture mass, however the intercept was important when trying to compare measured values with absolute targets, for example average pasture cover and post-grazing residuals, which are used regularly to provide targets for farmers.

Introduction

In grassland research and farming, pasture herbage mass is measured in order to derive herbage accumulation, allowance, consumption and for measurement and prediction of animal performance (Frame 1981). Hodgson (1979) defined herbage mass as "the total amount of herbage per unit of ground, usually measured to ground level but otherwise above a definite reference level which must be stated". In New Zealand most pasture estimations are assumed to be in terms of herbage mass above ground level. Herbage mass can be measured directly by cutting, but this is labour intensive and costly . As a consequence, methods have been developed based on the double sampling procedure, whereby the results obtained from a small area by cutting are used to predict values derived indirectly from larger areas (Vilm *et al.* 1944). In this paper, dried grass samples were used to obtain calibration equations for a rising plate pasture meter (Holmes 1974, Earle and McGowan 1979, Stockdale 1984).

A strong linear relationship has been found between individual methods and herbage mass for a given pasture on a particular day. These relationships or calibrations, however, can be influenced by factors such as the concentration of dead herbage in the dry matter (Jones and Haydock 1970; Currie *et al.* 1973), pasture species (Stockdale 1984; Crosbie *et al.* 1987), and sward compaction through trampling and lodging (Campbell *et al.* 1962). L'Huillier and Thomson (1988) published a set of seasonal calibration equations for the rising plate meter, where the environmental variation due to changes in season was the main source of variation between "indirect assessment methods" and "herbage mass" which are still considered to be appropriate 10 years later (Thomson *et al.* 1997).

The objectives of the present experiments were to derive calibration equations for the Rising Plate Meter (RPM) on Massey Number One Dairy farm which would measure any differences between seasons, and between irrigated and non-irrigated pastures, and between the three farming systems.

Materials and Methods

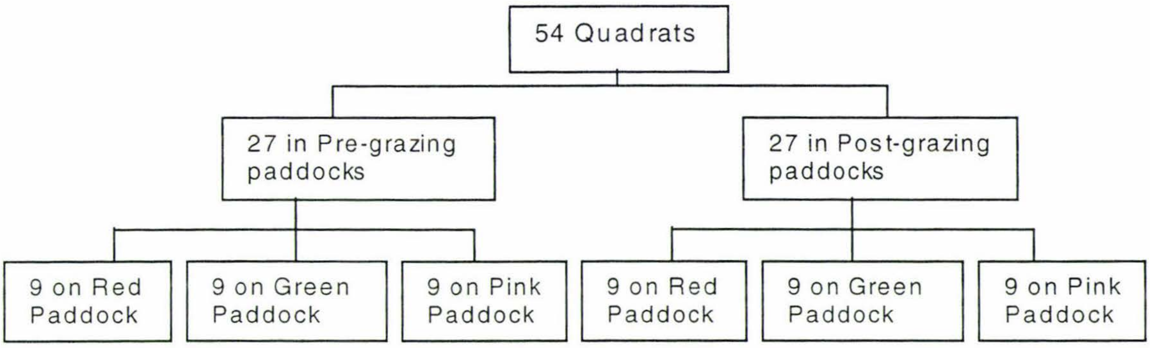
The study was undertaken at Massey University Number 1 dairy unit. The predominately perennial ryegrass-white clover pastures (>70%) were grazed all year round, by three separate herds on three separate farmlets. The details are given in Chapter 2. Measurements were made separately on the 3 farms.

Grazing management

Cows were grazed rotationally with strategic use of supplements, which were fed either on the feedpad, or in the paddock. Lactating cows may spend 3-4 days in a paddock, dry cows even longer. Access to fresh pasture is rationed by the use of an electric fence into 1-2 day allotments, with no electric fence behind the cows.

Pasture cuts

From mid-July 1998 to mid-December inclusive, monthly plate meter calibration cuts were taken in the early afternoon, with 54 quadrats cut from 6 separate paddocks on each of the 6 occasions as shown below.

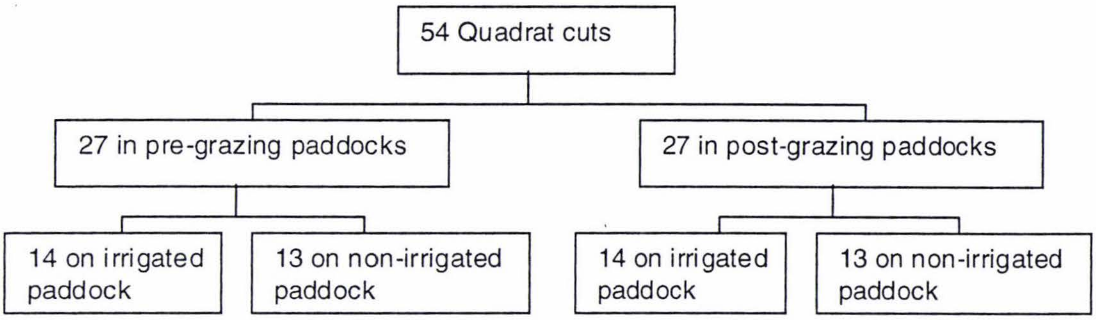


Monthly samples were divided evenly between the three farmlets, which were run separately on this farm (100% Autumn calving (Green), 100% Spring calving (Pink), and 50:50 autumn/spring calving (Red)). Details are given in Chapter 1.

Two paddocks were selected from each farm for sampling each month – the paddock that had just been grazed and the paddock that was going to be grazed next. The post-grazing quadrats were cut in paddocks that had been grazed by milking cows, except for those cut on the pink herd in July, which were from a paddock grazed by dry cows. Nine quadrat cuts covering a range of herbage mass levels were taken in each of the six paddocks, totalling 27 pre and 27-post-grazing quadrats, and 54 per month.

Quadrats on irrigated and non-irrigated paddocks

In early February, 54 quadrats were cut, 27 pre-grazing and 27 post-grazing, comparing irrigated and non-irrigated pasture. Four paddocks were used, with 13 or 14 cuts per paddock covering a range of herbage mass levels.



Irrigation scheme

The irrigation scheme covers an area of 9.3-ha using a 12-sprinkler irrigation line at 18m spacing (0.4-ha per line). Two 3.5-hour shifts are run per day (excluding weekends) allowing a 15-day rotation with 58-mm applied per shift and 116-mm per month. Historical average pan evaporation losses are 168, 143 and 115-mm/month for January, February and March respectively (AgResearch Grasslands Met Station), however the 1998/1999 summer was particularly high with evaporation losses of 204, 176 and 133-mm/month respectively (Figure 4-2). Irrigation was started on the 18/11/98 and continued (excluding weekends) until 18th March, with a brief spell including weekends between 27th February and 13th March. Mean pasture growth rates (PGR) are given in Figure 4-1.

Climatological information and additional farm information

These data were gathered from recordings already being collected on this experimental farm. This included information about the average farm pasture cover (kg DM/ha) for each herd which is assessed by a weekly farm walk, and pre and post-grazing residuals for the paddocks used in the experiment, both measured by the rising plate meter, as well as historical data on PGR (Figure 4-1). Daily climatological observations were used from Station E05363, which is adjacent to the Massey No. 1 dairy farm. Total monthly evaporation, rainfall, and average 9a.m. 10-cm soil temperature readings for April 1998 to March 1999 are shown in Figure 4-2

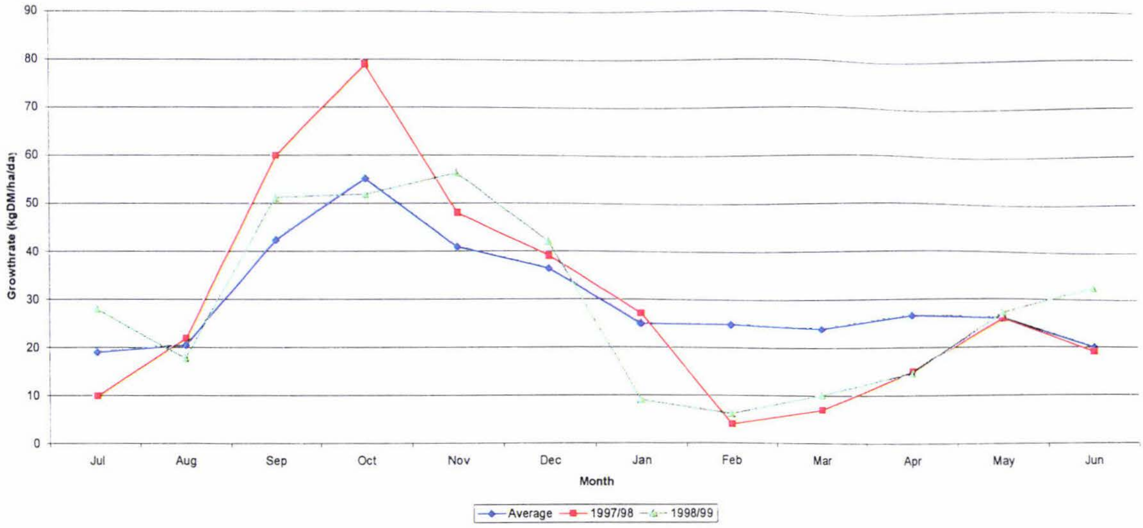


Figure 4-1 Monthly values for Pasture growth rates 1997-1998, 1998-1999 and the 10 year average valueFigure

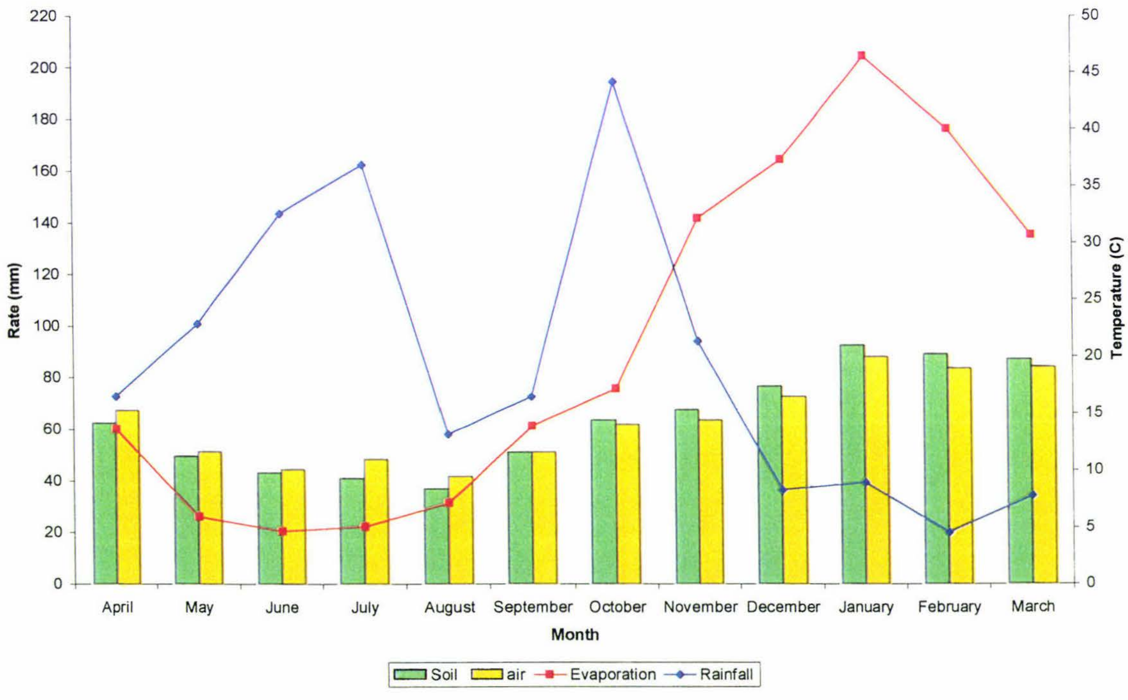


Figure 4-2 Total monthly evaporation and rainfall, and mean air temperature and 9a.m. 10cm soil temperature readings for April 1998 to March 1999

Measurements

The compressed heights of herbage in 0.1m^2 quadrats were assessed using a Rising Plate Meter (RPM) (Ashgrove Plate Meter, Ashgrove Pastoral Products, Palmerston North, New Zealand), using 1 reading per quadrat. Pasture on the quadrats was then cut to soil surface height using electric handheld shears, washed and dried for 24-36 hours at 80° C and weighed.

Analysis

The relationship between the indirect assessment of herbage mass (RPM) and actual herbage mass of the quadrat cuts (kgDM/ha) was determined using linear regression analyses for each month. PROC GLM (SAS Institute 1990) was used to test for differences between pre and post-grazing pastures, between irrigated and non-irrigated pastures, and between months. Equations from the present studies were then compared with published equations by predicting values for each line and summing the error residuals. These error residuals were then used as a ratio, providing an F-value that could be used to test for differences between these studies and published equations.

Results

Monthly calibrations

There were no significant differences in platemeter equations between farmlets (Green/Pink/ Red) for the six months data from July-December 1998 inclusive, or between irrigated/non-irrigated pastures in February (Table 4-1) (SAS Institute 1990). Therefore the data was pooled within month and the linear relationship, kg DM/ha = Plate meter reading was analysed monthly. The monthly equations are shown in Table 4-2 and Figure 4-3.

Table 4-1 Significance of the differences in rising plate meter calibration equations between irrigated and non-irrigated pastures (February 1999), between the farmlets (July-December 1998), and between months using PROC GLM (SAS Institute 1990)

item	*N[1]*	*significance*
irrigated *vs*, non-irrigated	53	NS
farmlet effect	323	NS
Pre *vs*. post grazing	377	NS
month	377	0.08

N[1] = Number of observations

Table 4-2 Rising plate meter equations for quadrats cut monthly over the period from July 1998 to February 1999. Climatological observations are also included. x = rising plate meter reading, and y = kg DM/ha). All months include pre and post-grazing samples; February includes pre and post-grazing, and irrigated or non-irrigated samples.

Month	*Calibration equation*		*Climatological conditions at the time of cutting.*
July	y = 77x + 1420	$R^2 = 0.24$	Ground very wet
August	y = 104x + 673	$R^2 = 0.59$	Wind gusty and cool
September	y = 124x + 821	$R^2 = 0.69$	Fine
October	y = 66x + 1567	$R^2 = 0.35$	some rain
November	y = 92x + 1289	$R^2 = 0.58$	Windy
December	y = 85x + 1959	$R^2 = 0.53$	Hot, light breeze
February	y = 148x + 1308	$R^2 = 0.59$	Hot, light breeze

These monthly equations are shown graphically in Figure 4-4, along with the published equations of L'Hullier and Thomson (1988), Livestock Improvement Advisory and Dairy Research Corporation (1999), and the general equation used by Massey University Number 1 dairy (y = 158x + 200). Whether the published and present studies lines are significantly different from each other (P<0.05) is shown in Table 4-3. All of the February equations were similar, with greatest variation in October, with only the Massey and L'Hullier and Thomson (1988) equations being not significantly different (P<0.05).

Figure 4-3 Comparison of monthly rising plate meter calibrations done on Massey No.1 dairy farm (points included to improve visibility of lines).

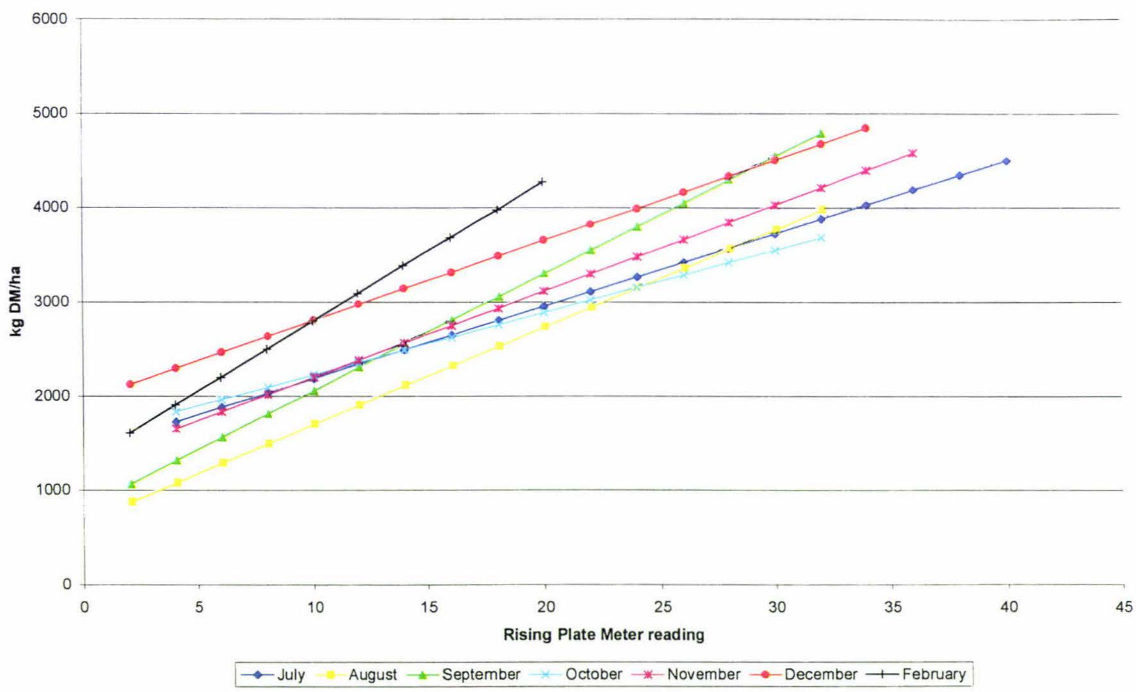
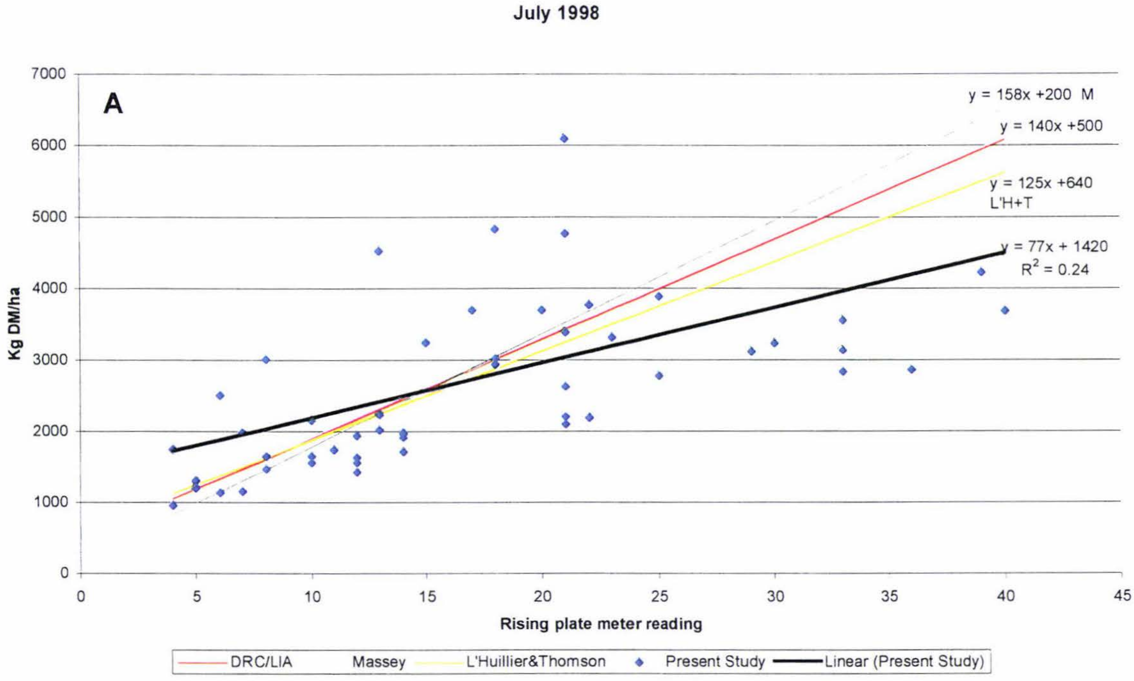
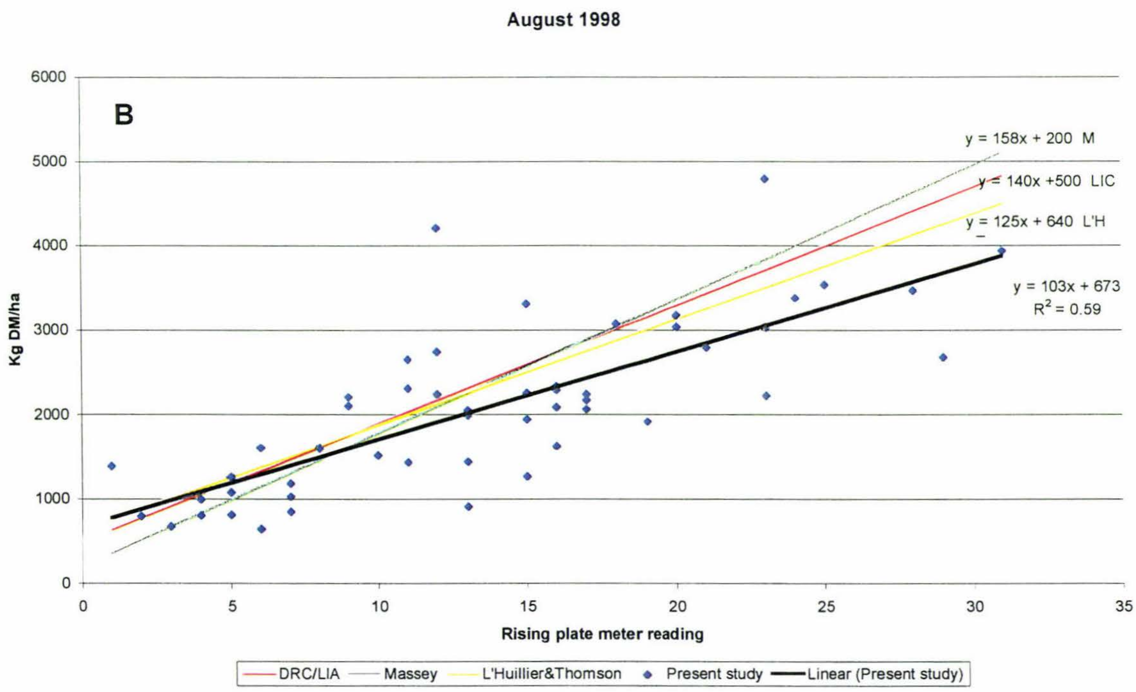
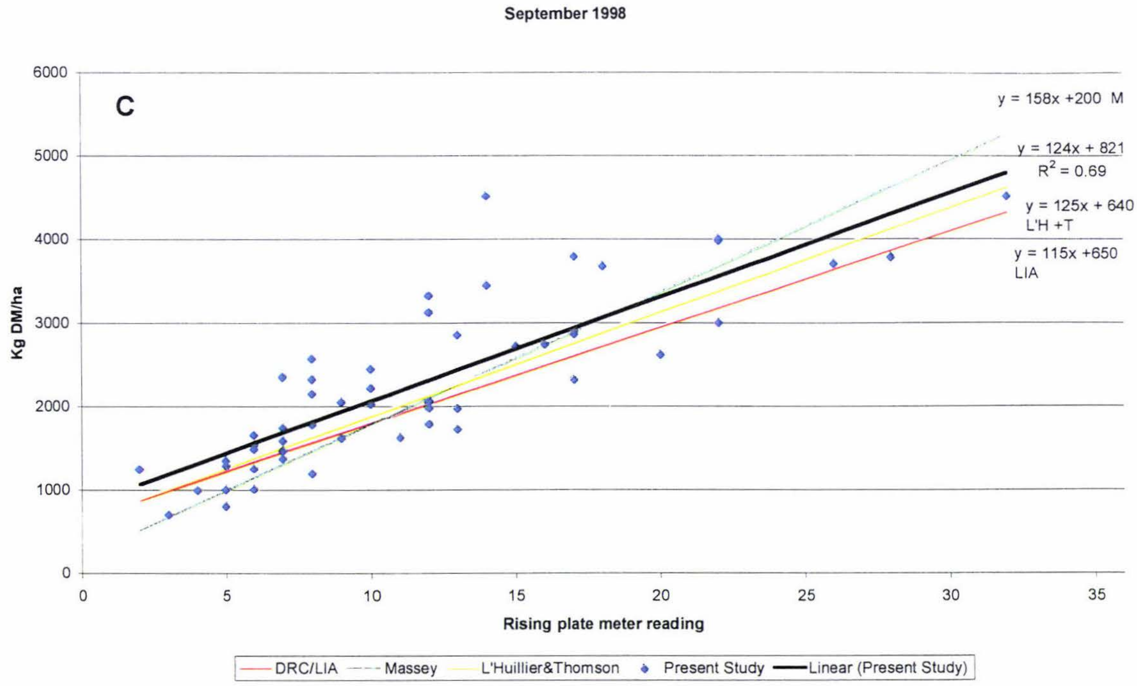
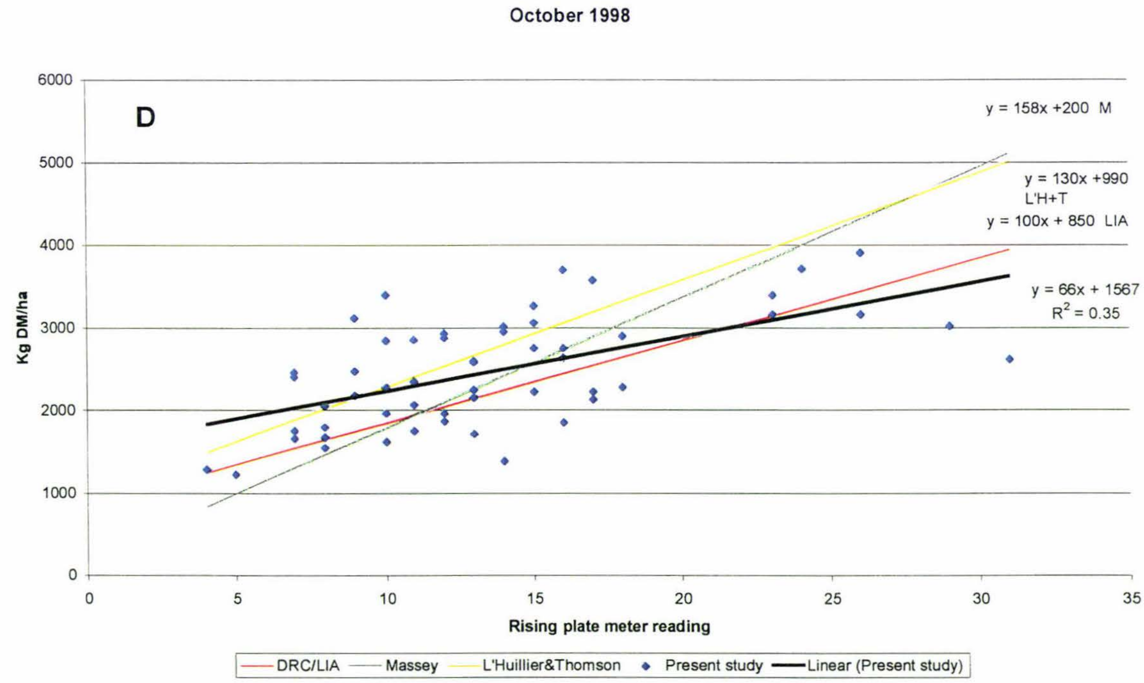


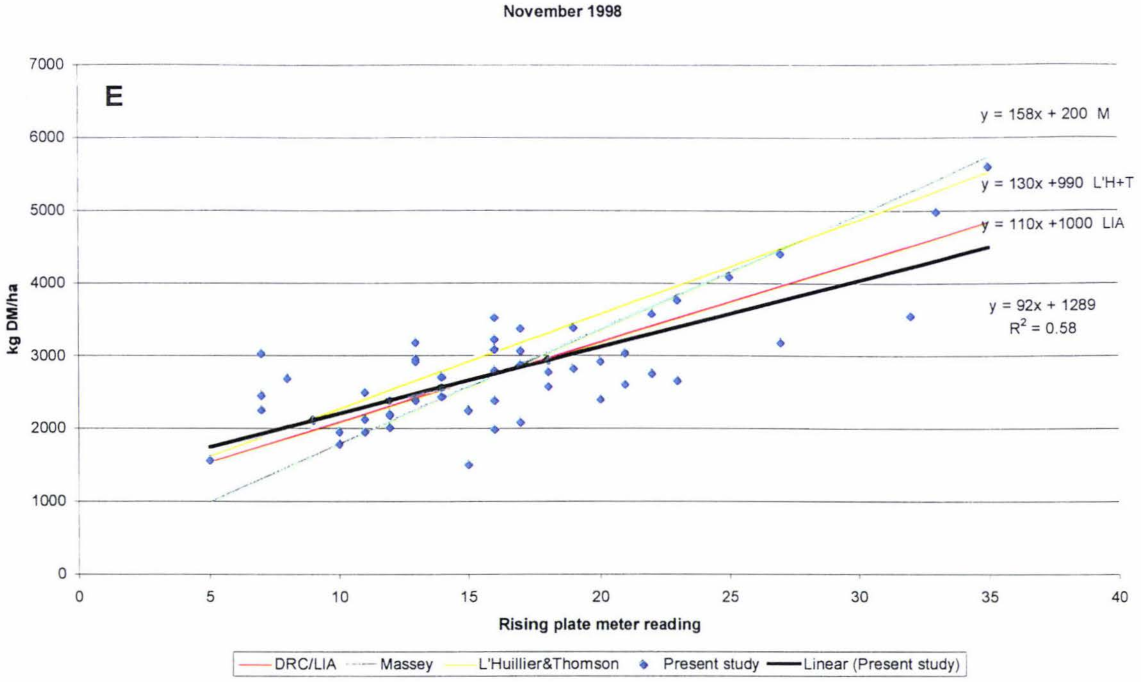
Figure 4-4 Monthly rising plate meter calibration cuts for each month from July 1998 (A) to February 1999 (G). Also included are; Massey equation (y = 158x +200), the appropriate seasonal equations of L'Huillier & Thomson (1988), and appropriate seasonal recommendations of Livestock Improvement Advisory (LIA) & Dairying Research Corporation (DRC) (1999).

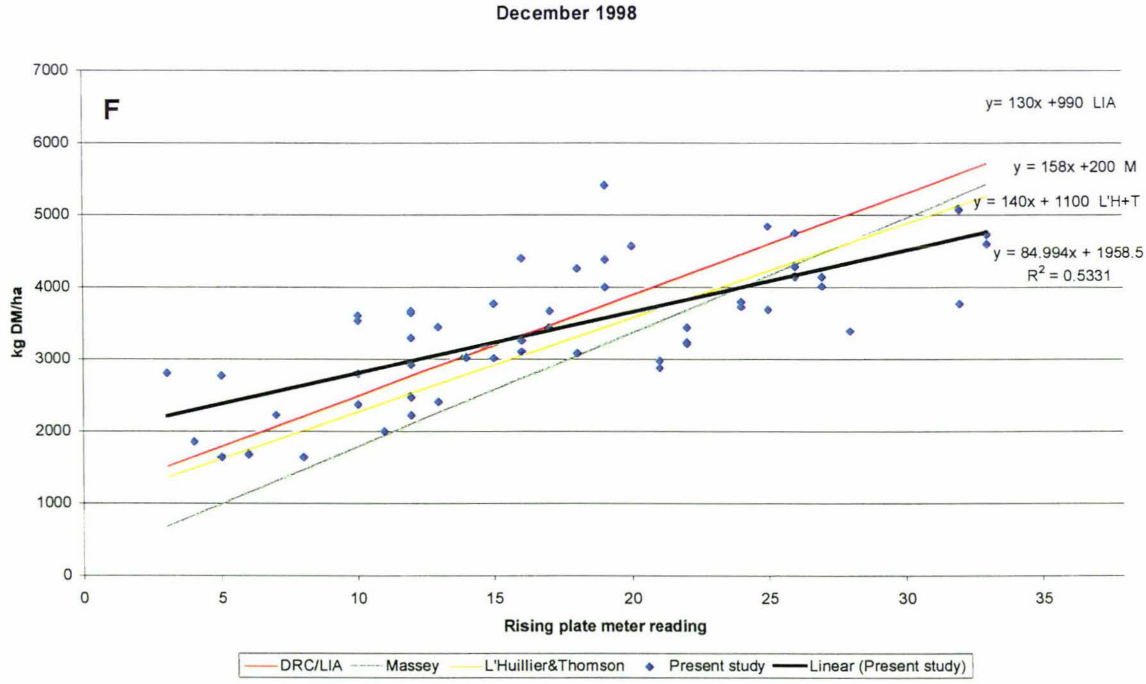





September 1998
C
y = 158x +200 M
y = 124x + 821
R^2 = 0.69
y = 125x + 640
L'H +T
y = 115x +650
LIA
Kg DM/ha
Rising plate meter reading
DRC/LIA
Massey
L'Huillier&Thomson
Present Study
Linear (Present Study)


October 1998
D
y = 158x +200 M
y = 130x +990
L'H+T
y = 100x + 850 LIA
y = 66x + 1567
R^2 = 0.35
Kg DM/ha
Rising plate meter reading
DRC/LIA
Massey
L'Huillier&Thomson
Present study
Linear (Present study)


November 1998
E
y = 158x + 200 M
y = 130x +990 L'H+T
y = 110x +1000 LIA
y = 92x + 1289
R2 = 0.58
kg DM/ha
Rising plate meter reading
DRC/LIA
Massey
L'Huillier&Thomson
Present study
Linear (Present study)


December 1998
F
y= 130x +990 LIA
y = 158x +200 M
y = 140x + 1100 L'H+T
y = 84.994x + 1958.5
R2 = 0.5331
kg DM/ha
Rising plate meter reading
DRC/LIA
Massey
L'Huillier&Thomson
Present study
Linear (Present study)

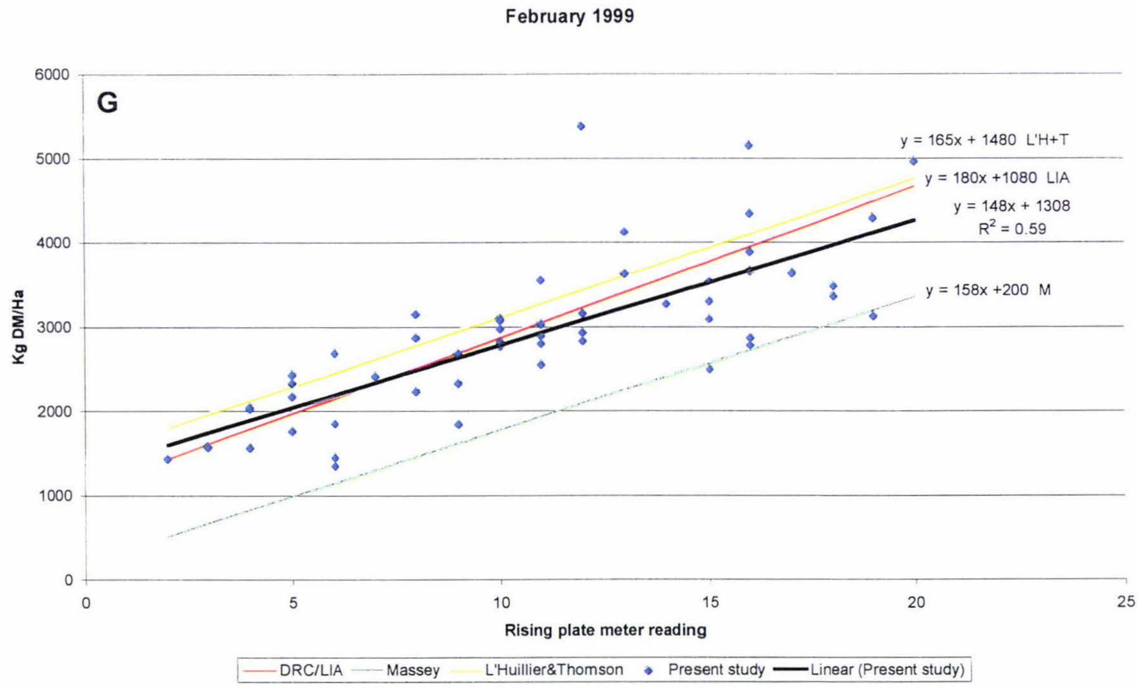


Table 4-3 Table of F-values comparing the published equations of L'Huillier & Thomson (1988), Livestock Improvement Advisory (LIA) & Dairying Research Corporation (DRC) (1999), the general equation of Massey, and present study for the months July - February.

Equation comparison	*July*	*August*	*September*	*October*	*November*	*December*	*February*
Massey vs. present	4.21	2.35	1.62	5.69	2.98	3.46	NS
LIC vs. present	3.31	1.85	NS	2.28	1.44	2.34	NS
L'Huillier vs. Present	2.64	NS	NS	3.85	2.02	2.71	NS
Massey vs. L'Huillier	1.60	1.60	1.60	NS	NS	NS	NS
Massey vs. LIA	NS	NS	1.89	2.50	2.06	NS	NS
L'Huillier vs. LIA	NS	NS	NS	1.69	NS	NS	NS

NS = Not significant at 5% level.

Recorded data from Massey Number 1 Dairy Farm between July 1998 and February 1999 has been used to extrapolate monthly plate meter estimations of pre and post-grazing (Figure 4-5) and average farm cover (Figure 4-6) for the present study, which is then compared with values calculated using the Massey equation (Table 4-4). Differences between pre and post-grazing residuals give a rough estimate of animal intake, and Table 4-5 shows how these two equations differ in these estimates.

Figure 4-5 Average monthly values of pre and post-grazing herbage mass (kg DM/ha) calculated from the Massey equation of y = 158x +200, (M), and the equations derived in the present study (P), between July 1998 and February 1999. Solid lines represent pre-grazing pasture yields, and the dotted lines represent post-grazing pasture residual.

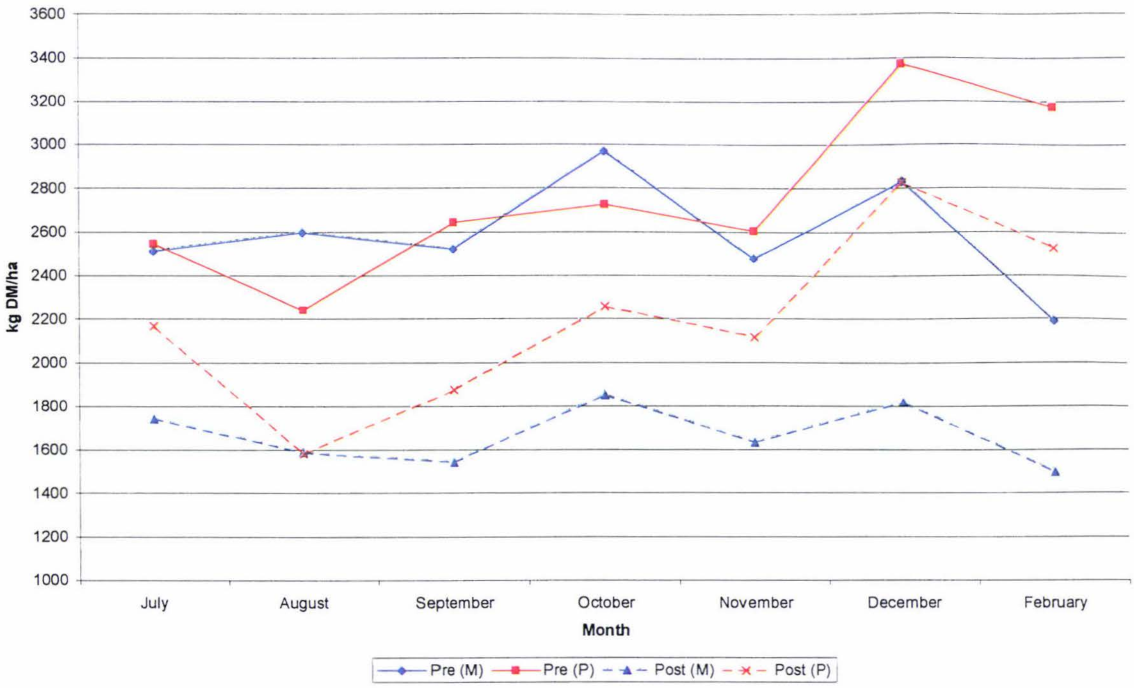


Figure 4-6 Average monthly values for farm cover calculated from the Massey equation of y = 158x +200, and the equations derived in the present study.

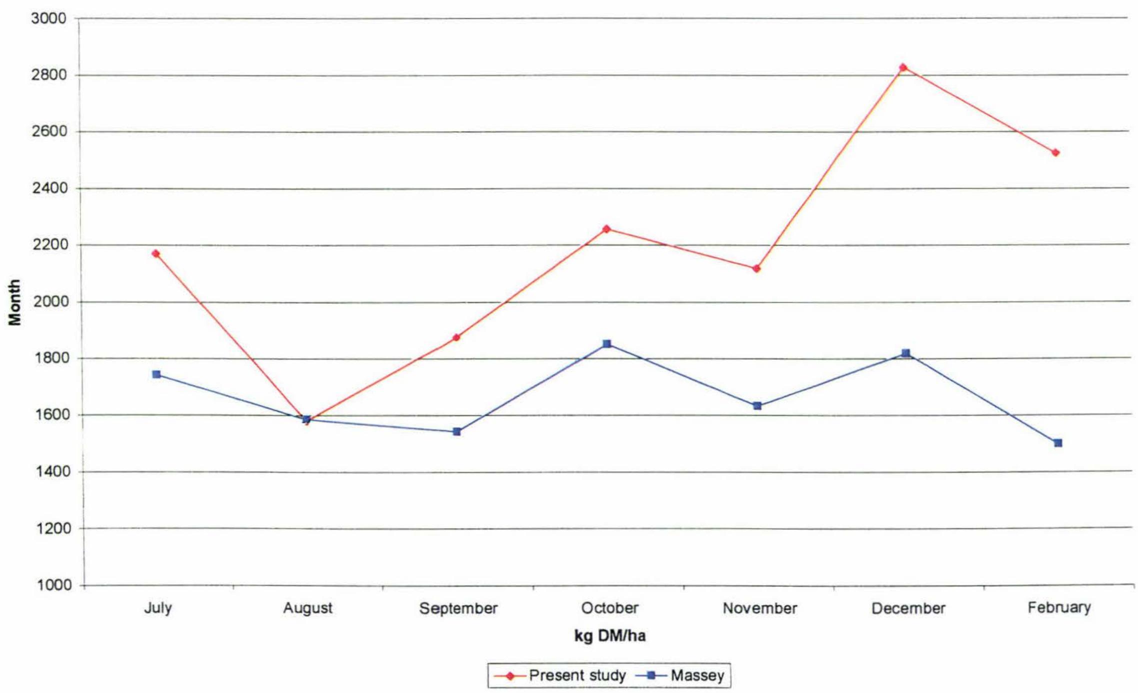


Table 4-4 Average monthly values monthly for pre and post-grazing herbage mass and average farm cover calculated from the Massey equation of y = 158x +200, and the equations derived in the present study.

Month	*Average pre-grazing (Kg DM/ha)*		*Average post-grazing (Kg DM/ha)*		*Average farm cover (Kg DM/ha)*	
	Massey	Experiment	Massey	Experiment	Massey	Experiment
July	2514	2547	1744	2173	2284	2436
August	2599	2244	1589	1583	2321	2062
September	2521	2647	1544	1878	1875	2139
October	2972	2729	1853	2260	2297	2446
November	2479	2609	1635	2120	2187	2440
December	2834	3376	1820	2830	2464	3177
February	2192	3177	1501	2529	1810	2819

Table 4-5 Values for the difference between herbage mass measured pre and post-grazing, - either the Massey equation or from the equations calculated in the present study.

Month	*Difference between pre and post-grazing (kg DM/ha)*		*Difference between the two values (kg DM/ha)*
	Massey	Present study	
July	770	374	396
August	1010	661	349
September	977	769	208
October	1119	469	650
November	844	489	355
December	1014	545	469
February	691	648	43

Discussion

Interactions

Differences between farmlets and between irrigated and non-irrigated paddocks were not significant as reported by Michell (1982) , but in contrast to the findings of Reeves *et al.* (1996). Pre-grazing calibration equations for the RPM did not differ significantly ($P<0.01$) from post-grazing calibration. This allowed general equations to be developed for each month. Specific equations have been advocated for each month by LIA (1999) for regular farmer use, except during the winter when one equation covers the period.

The correlations of data within these equations were affect by ground conditions, such as wetness more than wind. This was demonstrated in July and October, where cuts were taken in wet ground conditions with R^2 values of 0.24 and 0.35 respectively. The present equations were characterised by larger intercepts and smaller regression coefficients than those reported from recently published New Zealand data. Stockdale (1984b) considered the rising plate meter to be more accurate on pre than post-grazing residuals, however Reeves *et al.* (1996) found pre and post-grazing estimates were of similar precision. In this study results were mixed, over the winter and summer pre-grazing RPM estimates were more accurate, and over spring post-grazing estimates more so.

Practical on-farm use

One of the main uses for a rising plate meter on farms is to rank the paddocks in terms of kg DM/ha, although is can also provide an estimate of pasture intake per cow using pre and post-grazing recordings (Livestock Improvement Advisory and Dairying Research Corporation Limited 1999). When used for either of these reasons, the slope of the line is more important than the intercept. The intercept provides a common base to work from, with the interest being in the relative difference between results. Actual pasture height or herbage mass is not important. This is best shown in February, where all equations were shown to be similar, with slopes ranging between 148x and 180x, where x is the RPM reading, and the Massey and present study estimated similar animal intakes from the difference in pre and post-grazing residuals, despite intercepts differing by 1100.

There is an increase in herbage mass close to the ground during summer which then declines in the autumn (Frame and Hunt 1971); (Michell 1982). Therefore when comparing actual values for pasture yields to published recommendations (such as average farm cover, and post-grazing residuals), the intercept of an equation is also important. This is demonstrated in February where Masseys' intercept of 200 is much smaller than that in the present study and other published intercepts of 1080 – 1480. This led to a 1000kgDM/ha difference in estimation of important targets such as average farm cover and post-grazing residuals when comparing the present study and Masseys' equation.

Conclusions

Herd, irrigation, and whether pre or post-grazing residuals were used did not affect the equation derived for the RPM. Month had a significant effect on calibration; hence monthly equations were derived for the RPM. The slope of an equation proved to be the most important for accurate estimation of pasture mass, with results all being relative to the same 'base line', or intercept. Where targets values are aimed for (such as average pasture cover, and post-grazing residuals quoted to farmers by consultants), the intercept is also important, as this affects the actual herbage DM figure produced.

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CHAPTER 5

General Discussion

Grazing behaviour

This research on the seasonal grazing behaviour of dairy cattle can be divided into five broad sections. The effect of Supplementation; Calendar season; Stage of lactation; Sward conditions and pasture height, and the effect of age. These topics will be summarised and discussed in this chapter.

Supplementation with other feeds

Table 5-1 Summary of least squares means (±SE) for ingestive behaviour parameters of supplemented and non-supplemented autumn calved cows offered generous herbage allowances.

item	*Supplemented*	*non-supplemented*
Daily intake (kg DM per cow)		
Pasture	10.8 ± 0.52	12.1 ± 0.79
Maize silage	2.9 ± 0.18	0.0 ± 0.28
Total	13.7 ± 0.58	12.2 ± 0.88
Milksolids production (kg/cow/day)[1]	1.46 ± 0.06	1.47 ± 0.09
Total grazing time (min./day)	546 ± 16.9	615 ± 24.7
Total ruminating time (min./day)	403 ± 12.0	333 ± 17.6
Intake rate (g DM/min. grazing time)	19 ± 1.04	19 ± 1.52

[1] Milksolids (MS) = fat (kg) + protein (kg)

Supplementation influenced the quantity and relative proportions of grazing, ruminating and idling times. Substitution of pasture by maize silage occurred, with reductions in pasture intake averaging 0.52-kg pasture DM eaten of maize silage, and grazing time averaging 24-minutes per kg supplement DM eaten, which is similar to the reported values of 37 and 30-minutes per kg by Phillips and Leaver (1986b). This figure is much lower than the value of 43-min. for each kilogram of silage DM consumed reported by (Mayne *et al*, unpublished results; cited by Mayne (1991)) . Stockdale (1996) studied the effect of pasture allowance on substitution rate, and found maize silage substitution rates of 0.14 and 0.40-kg pasture DM/kg supplement DM eaten for pasture allowances of 19 and 39-kg DM/cow/day respectively. These are consistent with the present value of 0.52 for an herbage allowance of 64-kg DM/cow/day. The changes in behaviour occurred particularly during daylight hours, with the cows not receiving supplements (non-supplemented) spending 58% (358-minutes) of their daylight hours grazing compared to the supplemented cows which spent 44% (281-minutes) of daylight hours grazing. The supplemented cows increased their rumination time during the day, probably because the maize silage was fed after morning milking. Increased rumination also occurred at night, in preference to idling.

The increase in total rumination time by supplement cows was expected not only because of their higher total DM intake, but also due to their relatively quick intake of the more fibrous, less digestible maize silage in the morning before grazing. The supplemented and non-supplemented cows ruminated for 29 and 27-min./kg DM respectively of their total daily intake, which are similar to the 28-min./kg herbage DM reported by Phillips and Leaver (1986a) for cows in early season. Supplemented cows tended to idle for less time, suggesting that availability of idling time may not be the only factor that limits the sum of grazing time and ruminating time per 24-hours which has been proposed by Woodward (1997).

The supplemented heifers ate a smaller proportion of their diet (16% *vs.* 22%) as maize silage than the mature cows, probably due to the increased competition for feed around the bins where the supplement was fed. Heifers did not therefore decrease their absolute grazing time or pasture intake to the same extent as mature cows. Heifers and mature cows showed the same changes in general behaviour patterns in response to supplementation, however the effects of supplementation were significant only in mature cows. The general trend was for non-supplemented cows to graze for longer times, and ruminate for shorter times per 24-hours.

Intake rate was not affected by supplementation. However heifers and mature cows responded differently to supplementation. General bite characteristics were not changed in the mature cows, although non-supplemented mature cows tended to take faster, smaller bites, and grazed for a significantly longer time compared to mature supplemented cows (which therefore significantly increased their total bites per day). However non-supplemented heifers significantly decreased their bite rates (BR), and generally increased their bite weight.

Calendar season

Table 5-2 Summary details of the three present trials

	Winter (EXP3)[2]	Spring (EXP1)	Summer (EXP2)
Daily pasture intake (kg DM per cow)[1]	12.2 ± 0.88	15.9 ± 0.42	16.6 ± 0.37
Hours of daylight	10.5	12	15
Minutes spent grazing during daylight[1]	358 ± 19.2	348 ± 5.0	443 ± 4.5
Total minutes spent grazing per day[1]	615 ± 24.6	590 ± 5.7	521 ± 5.1
Intake rate (g DM/min.)	19 ± 1.52	27 ± 0.83	32 ± 0.75

[1] mean ± S.E.
[2] Observations for non-supplemented cows only.

Approximately 58%, 59%, and 85% of the grazing activity took place during daylight hours for July (10.5-hours daylight) (EXP3), September (12-hours daylight) (EXP1), and December (15-hours daylight) (EXP2) respectively, with distinctive peaks of grazing activity just after the morning and afternoon milkings.

Cows preferred to graze during daylight hours, as shown by Penning *et al.* (1991b) with sheep, and Phillips and Leaver (1986b) with cows. Grazing activity peaked after morning and afternoon milkings, and again just before dusk, but declined sharply after dusk. The number of night-time grazing peaks was dependent on the length of darkness, and how much grazing was required to be done at night because it had not been done during daylight due to short daylength. Cows spent between 47-57% of the daylight hours grazing, but the actual available time spent grazing was actually less, as the cows were away at milking for on average 3-hours per day. Similar figures for the proportion of daylight hours spent grazing were found by Rook *et al.* (1994). Whatever remaining grazing time was required to satisfy requirements then occurred during the night (15-33 % of night-time hours), with less grazing been done during the night when daylength was longer. It must be noted that throughout the 24-hours feed was readily available with high herbage allowances of between 55 and 63-kg DM/cow/day. Post-grazing residuals were generous averaging between 1800-kg DM/ha (July) and 2800-kg DM/ha (December).

Stage of lactation

Table 5-3 Least squares means (±SE) for ingestive behaviour parameters of autumn and spring calved cows offered generous herbage allowances.

Item	*September*		*December*	
	Autumn calved	Spring calved	Autumn calved	Spring calved
Herbage intake (kg DM/cow/day)	15.4 ± 0.51	16.3 ± 0.51	16.7 ± 0.58	16.4 ± 0.59
Milksolids production (kg DM/cow/day)[1]	1.32 ± 0.05	1.72 ± 0.05	1.07 ± 0.03	1.30 ± 0.03
Liveweight (kg)	509 ± 8.0	465 ± 7.0	546 ± 9.5	481 ± 9.6
Grazing time (min/day)				
Day	343 ± 7.1	354 ± 7.2	454 ± 6.2	431 ± 6.3
Night	228 ± 7.2	253 ± 7.2	68 ± 4.6	90 ± 4.6
Total	571 ± 8.3	609 ± 8.4	521 ± 6.8	522 ± 6.9
Total ruminating time/kg DM eaten	23.0 ± 0.79	23.4 ± 0.79	28.2 ± 0.77	30.6 ± 0.78
Bite rate (bites/min)	56 ± 0.7	57 ± 0.7	51 ± 0.7	49 ± 0.7
Intake rate (g DM/min)	27 ± 0.91	27 ± 0.92	32 ± 1.22	32 ± 1.24

[1] Milksolids = protein (kg) + fat (kg)

The grazing times shown in Table 5-3 are representative values of fully fed Holstein-Friesian cows, and fell within the range of other estimates reported in the literature (García-Muñiz 1998; Hodgson and Jamieson 1981; Phillips and Denne 1988; Phillips and Leaver 1986b; Gibb *et al.* 1997).

Stage of lactation had no effect on the bite characteristics (such as bite rate, bite weight, and hence intake rate) of the cows. However it did affect the total grazing time of cows in early lactation because of the higher milk yields and metabolic requirements of these cows. In September the cows with lower feed requirements (autumn calved) grazed as efficiently, but for less total time than the cows with higher feed requirements. Specifically they maintained or even increased the proportion of daylight hours spent grazing, but decreased the proportion of night-time grazing, preferring to idle (i.e. sleep). However by December, these different metabolic requirements had largely disappeared, due to the spring calvers decreased milk production, and the autumn calvers being in the last third of pregnancy. Rumination times remained similar per kg DM eaten between differing stages of lactation.

Sward conditions and pasture height and mass

Table 5-4 Summary details of the three trials

	Winter (EXP3)[4]	*Spring (EXP1)*	*Summer (EXP2)*
Pre-grazing herbage mass (kg DM/ha)[1]	2758 ± 430	2879 ± 358	3387 ± 174
Post-grazing herbage mass(kg DM/ha)[1]	1760 ± 387	1990 ± 239	2847 ± 99
Pasture intake (kg DM/cow/day)[2]	12.2 ± 0.88	15.9 ± 0.42[3]	16.6 ± 0.37[3]
Milksolids production (kg MS/cow/day)[2]	1.47 ± 0.09	1.52 ± 0.03[3]	1.19 ± 0.03[3]
Pasture composition			
Dry matter (%)[1]	14.0 ± 0.5	13.7 ± 2.1	14.0 ± 2.4
Organic matter digestibility (g/100 g DM)[1]	74.1 ± 1.2	87.7 ± 2.6	71.3 ± 3.4
Neutral Detergent Fibre (g/100 g DM)[1]	39.8 ± 0.7	40.5 ± 1.5	48.9 ± 1.4
Crude protein (g/100 g DM)[1]	26.3 ± 2.1	30.1 ± 2.5	19.0 ± 2.0
Grazing behaviour			
Total minutes spent grazing per day[2]	615 ± 24.6	590 ± 5.7	521 ± 5.1
Total grazing time per day (min./kg DM eaten)[2]	53 ± 4.59[MC1]	38.6 ± 0.74	33.4 ± 0.65
Total ruminating time per day (min./kg DM eaten)[2]	28 ± 2.62	23 ± 0.59	29 ± 0.53
Bite rate (bites/min)[2]	59 ± 1.7	57 ± 0.5	50 ± .5
Bite weight (mg DM/bite)[2]	316 ± 25.29	485 ± 16.94	662 ± 15.34
Intake rate (g DM/min.)[2]	19 ± 1.52	27 ± 0.83	32 ± 0.75

[1] mean ± S.D
[2] mean ± S.E.
[3] average of autumn and spring cow production.
[4] data for non-supplemented cows

Sward characteristics can have major effects on grazing time, intake per bite and biting rate by grazing cattle. The proportion of fibre needed to maintain a constant milkfat content increases as the level of intake increases (Broster *et al.* 1985). Stockdale *et al.* (1987) reported that milkfat concentrations declined when the neutral detergent fibre content of the diet was below 25% in cows fed irrigated spring pasture. In the United Kingdom, Chamberlain and Wilkinson (1996) recommended that the neutral detergent fibre component of the diet of lactating cows should be 35-40%. In Victoria, Stockdale *et al.* (1997) suggested a range of 25-35% NDF, with requirements increasing as food intake increases. Wilson *et al.* (1995) suggested even higher values of 35-45% NDF were appropriate in New Zealand. Above the recommended level, there can be negative effects of fibre on total feed intake and the rate of supply of volatile fatty acids can be too slow to enable high-producing cows to realise their potential.

Determining the protein requirements for livestock based on particular levels of crude protein in the diet is considered inaccurate (AFRC 1992). Dietary protein is made up of rumen degradable and rumen undegradable (bypass) components. High-producing dairy cows, in particular, require undegraded dietary protein (AFRC 1992), but the proportion of pasture protein which escapes rumen fermentation is poorly defined. In cows grazing pasture alone, a knowledge of the rumen degradable and undegradable components of pastures has not been an important issue, since energy is the primary limiting nutrient under these circumstances (Stockdale *et al.* 1997). Wilson *et. al.* (1995) recommended ideal values for CP between in New Zealand to be between 14 and 20%. In addition, a high dry-matter (e.g. 15+%) is important to avoid intake limitations due to the amount of water. With these general values it is considered that the digestibility of the pastures will determine intake, which together with nutritive value (such as MJ ME) will determine performance (Wilson *et al.* 1995).

The spring pastures in EXP1 should have encouraged high intakes of energy due to the low NDF and high digestibility, but the crude protein present is much higher than required, and the high water content in the immature spring pasture may have limited intake by the cows (Wilson *et al.* 1995). Cows ruminated for only 22 min./kg DM in EXP1, probably due to the low NDF value of the pasture. However there is also indirect evidence that the elastic nature of the NDF fraction in fresh pasture may reduce its effectiveness in the rumen (Kolver *et al.* 1996). Effective fibre is essential to buffer rumen acidity. Very high levels of protein (30% or more) are detrimental because excess protein cannot be captured by the rumen bacteria and is instead absorbed as ammonia and converted to urea by the liver. This process requires considerable metabolisable energy, which is then not available for milk production or maintenance of the cow. It is therefore possible that the cows in EXP1 may have had a higher peak production if CP had been lower (Wilson *et al.* 1995).

The summer pastures in EXP2 relative to the EXP1 had higher fibre concentration and lower digestibility, with energy intake potentially being limited (suggested by the low MS Production in summer (EXP2)), with a value of only 10.6-MJME/kgDM. Very high levels of fibre (NDF >45) such as in EXP2 are associated with low digestibility and reduced intake (Wilson *et al.* 1995; Chamberlain and Wilkinson 1996). Changes in pasture composition in late spring are partly are due to grasses reaching their 'reproductive stage'. The cell wall constituents (cellulose, hemicellulose and lignin) increase and most of the plant cell constituents (protein, and minerals) decrease with increasing maturity (Brookes and Wilson 1997). Cows in EXP2 had higher herbage intakes than in EXP1, despite the NDF values being above those recommended by Stockdale *et al.* (1997) , Chamberlain and Wilkinson (1996) and Wilson *et al.* (1995) . However, grazing cattle are able to preferentially select parts of the sward, so the composition of the diet consumed will differ from that on offer.

The winter pasture in EXP3 had high levels of CP, potentially limiting MS Production, as in EXP1, due to the energy cost of the absorbed ammonia being converted to urea by the liver. The levels of NDF suggest this should have not been a problem, however intake of pasture was low, and ruminating times/kg DM herbage DM eaten were equivalent to the summer pastures in EXP2, which had high NDF values. Potentially the pre and post-grazing residual may have limited herbage intake, with the cows taking faster bites of less weight compared to the other experiments, with a lower intake rate (Allden and Whittaker 1970; Hodgson 1986; Greenwood and Demment 1988).

Cows increased their ruminating times per kg DM eaten between EXP1 (spring) and EXP2 (early summer), as the season progressed. This is consistent with the trend reported by Phillips and Leaver (1986a) of 28, 35 and 43-minutes in early, mid and late season respectively, and is explained by the increasing NDF values of the pasture as it matured. Most of the ruminating (67-78%) was concentrated into the hours of darkness, but it was also interspersed between the major grazing bouts during the daylight hours.

The importance of the plate meter calibration equation is highlighted in conditions where absolute values for pre and post-grazing residuals are may be limiting factors of herbage intake (suggested by the increased bite rate, bite weight and decreased rate in EXP3 compared to EXP1 or EXP2). If the plate meter is not estimating the correct herbage DM, post-grazing residuals may be overestimated, which could result in reduced cow intake if recommended post-grazing residuals are being used as a guideline of grazing pressure. In the present experiments, the grazing conditions were managed to what were before the experiments considered to be high pre-grazing (2879 ± 358 (EXP1)), (3381 ± 174

(EXP2)), (2758 ± 430 (EXP3)) and high post-grazing (1990 ± 239 (EXP1)), (2847 ± 99 (EXP2)), (1760 ± 387 (EXP3)) (mean ± SD) pasture mass (kg DM/ha).

Management conditions were such that was thought unlikely to create sward conditions that would limit intake per bite and therefore trigger an increase in biting rate, grazing time and hence total number of bites (McGilloway and Mayne 1996). However cows grazed for longer during EXP3 where post-grazing and pre-grazing residuals were the smallest (50 (winter-EXP3), 39 (spring- EXP1), and 33 (summer-EXP2)-min./kg DM eaten). Between EXP3, EXP1, and EXP2 there were increasing intake rates, with slower bites of larger weight. Increased biting rate is regarded as a compensatory mechanism triggered by a lower bite weight, and displayed in order to maintain total daily intake when sward conditions, especially height (Phillips 1993), or mouth size, i.e. a narrower incisor arcade breadth, (Illius and Gordon 1987) become limiting. EXP3 was characterised by low bite weight (316 mg DM/bite), compared to values ranging between 408 to 528-mg DM/bite for genetically light and heavy cows (García-Muñiz 1998), which were similar to the values recorded in EXP1 (485-mg DM/bite), and EXP2 (662-mg DM/bite).

The effect of age

Table 5-5 Summary of parameters of ingestive behaviour of heifers and mature cows. Values of experiments 1, 2, and 3 are presented here as average values

item	*Heifer*[2]	*Mature*[2]
Daily pasture intake (kg DM/cow)	12.9	15.3
Milksolids production (kg MS/cow/day)[1]	1.18	1.45
Total grazing time (min/cow/day)	574	579
Total Ruminating time (min/cow/day)	380	380
Bite rate (bites/min)	58	56
Bite weight (mg DM/bite)	423	507
bite weight (mg DM/kg $LW^{0.75}$)	4.5	4.6
Intake rate (g DM/min)	23	27
Intake rate (g DM/kg $LW^{0.75}$/min	253	237

[1] Milksolids = fat (kg) + protein (kg)

[2]EXP1 incorporates the non-supplemented cows only.

Heifers are often at the bottom of the dominance order in a herd due to their age and lighter weight (Stakelum *et al.* 1987). Rutter *et al.* (1987) found cows lower in the dominance order ate more at night, however this was not shown by Stakelum *et al.* (1987) or in these experiments. In this study, heifer grazing times and patterns were similar to those of mature cows despite significantly smaller intakes in EXP2 and EXP3. Therefore heifers had slower intake rates (g DM per minute), and they spent longer ruminating per kg of DM. Heifers ate smaller bites than for mature cows, but they did not always have faster bite rates, which is consistent with the findings of Phillips and Leaver (1986a) .

Heifers graze for the same total amount of time as mature cows, yet they eat less due to their smaller bite size. Either heifers are not physically able to, or do not have the inclination to, eat herbage at a faster rate, or bullying by older animals higher up in the social hierarchy has an influence on heifer intake rate. The results of Stakelum *et al.* (1987) suggest that, under grazing systems, social interactions between cows are unlikely to inhibit or restrict their herbage intake or grazing behaviour. Either way, the heifers are not willing to graze for any longer than mature cows, despite their slower rate of intake, strongly suggesting that social factors are an important factor in grazing behaviour. Heifers would need to be grazed separately from mature cows in order to test their ability to increase their intake rate or grazing time, without the social interaction of more dominant cows.

Use of the Rising Plate Meter and its calibration

The main roles of a Rising plate meter (RPM), as discussed by LIA and DRC (1999) are to assess average pasture cover, and to measure Total Herbage Mass, assessed as amount of pasture above ground level as kg DM/ha. The RPM is not considered to be a good predictor of pre- and post-grazing residuals, or of cow intakes. As such, although pastures that were about to be grazed and pastures that had just been grazed, were used as selection criteria for paddocks to be calibrated, it was not considered practical to derive separate pre- and post-grazing calibration equations. Differences between farmlets and between irrigated and non-irrigated paddocks were not significant, in agreement with Michell (1982), but in contrast to the findings of Reeves *et al.* (1996). This allowed specific monthly equations to be derived, as has been advocated by LIA and DRC (1999) for regular farmer use, except during the winter when one equation is considered sufficient to cover a period of 5-months.

The correlations of data within these equations were affected by ground conditions, especially by wetness. This was demonstrated in July and October, where cuts were taken in wet ground conditions with R^2 values of 0.24 and 0.35 respectively. The present equations were characterised by larger intercepts and smaller regression coefficients than those reported from recently published New Zealand data (L'Huillier and Thomson 1988, Livestock Improvement Advisory and Dairying Research Corporation Limited 1999). Stockdale (1984b) considered the rising plate meter to be more accurate on pre-grazing masses than post-grazing residuals, however Reeves *et al.* (1996) found pre and post-grazing estimates were of similar precision. In this study results were mixed, with pre-grazing RPM estimates being more accurate over the winter and summer, and post-grazing estimates being more accurate over the spring.

One of the main uses for a rising plate meter on farms is to rank the paddocks in terms of kgDM/ha, although it can also be used as a rough guide of animal intake (Livestock Improvement Advisory and Dairying Research Corporation Limited 1999), and is indeed used as such by some researchers. When used for these purposes, the slope of the line is more important than the intercept. The intercept provides a common base line to work from, with the main interest being in the relative difference between results (due to the slope). Actual pasture height or herbage mass is not critical. This was demonstrated when comparing the February equation derived in this study ($y = 148x + 1308$), and the February RPM equation used by Massey University on its Number 1 dairy farm ($y = 158x + 200$), where y = kg DM/ha, and x = the rising plate meter reading. Both equations estimated similar animal intakes from the difference in pre and post-grazing residuals, despite intercepts differing by 1100.

There is an increase in herbage mass contained in the strata close to the ground during summer, which then declines in the autumn (Frame and Hunt 1971, Michell 1982). The intercept value of a calibration equation is the important component in estimating this, and therefore it will inevitably vary from month to month. Consequently when an accurate estimate of actual pasture herbage mass is required, the intercept is very important. Absolute pasture herbage mass values are particularly important when making comparisons with pasture targets, which are key tools in farm management strategies, such as average pasture cover, and post-grazing herbage residuals. This was demonstrated in February where intercept of the Massey RPM equation (200) was much smaller than that derived in the present study and other published intercepts of between 1080 and 1480. This led to a 1000-kgDM/ha difference in estimation of important targets such as average farm cover and post-grazing residuals when comparing the present study and Massey February equation. An underestimation of pasture cover at this time of the year might lead to unnecessary drying off of cows, use of supplements, or a farmer who is more stressed than is absolutely necessary! Hence the importance of correctly derived RPM equations. Consistency of targets between farms is important for the comparison of between farm systems, and for comparing farm systems on a common basis.

Conclusions

The following conclusions can be drawn:

- Grazing behaviour of lactating dairy cows remains consistent throughout the year, in that they prefer to grazing during daylight hours, but as they can only graze for about 50% of any period of time, they are required to always graze at night to some extent (unless daylight lasts for about 20-hours per 24-hours).

- Bite characteristics (bite rate, bite weight, and intake rate) were not affected by stage of lactation. Bite weight was larger, and bite rate was slower in summer than in spring, in association with heavier pasture masses.

- Bite characteristics such as bite size, rate, and intake rate were not affected by offering maize silage; however grazing time was reduced by cows consumption of maize silage.

- Heifers are not willing or able to graze longer than the mature cows (although theoretically it is possible), to make up for their smaller bite size and consistently slower intake rate.

- 10.3 hours is near the maximum grazing time possible for lactating cows.

- The equations derived for the RMP were not effected by irrigation or by the differences between pre and post-grazing pasture residuals.

- Month had a significant effect on the calibration equations for the RMP, therefore monthly equations were derived.

- The slope of a calibration equation is the most important characteristic for accurate comparisons of pasture masses within a system, however the intercept is important when comparisons are made with absolute targets (such as average pasture cover, and post-grazing residuals).

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Appendices

Appendix 2.1 – Example of grazing sheet used for cows in September trial. Observers filled in the appropriate letter, where G = grazing; R = Ruminating; I = Idling.

Observer					Time:								Date								
Cow no	Collar colour	0-10	10-20	20-30	30-40	40-50	50-60		0-10	10-20	20-30	30-40	40-50	50-60		0-10	10-20	20-30	30-40	40-50	50-60
123	G																				
126	G																				
127	Y																				
129	O																				
138	O																				
139	P																				
140	Y																				
141	O																				
146	G																				
147	Y																				
148	G																				
149	O																				
150	P																				
159	P																				
168	P																				
169	P																				
174	Y																				
176	P																				
178	P																				
181	P																				
185	P																				
188	P																				
190	G																				
194	O																				
195	Y																				
196	Y																				
198	O																				
200	G																				
207	O																				
208	O																				
213	Y																				
215	G																				
217	O																				
218	Y																				
219	Y																				
220	O																				
221	Y																				
222	G																				
223	P																				
227	O																				
228	G																				
229	G																				
234	P																				
235	G																				
241	O																				

Appendix 2.2 Example of grazing sheet used for cows December trial. Observers used a black vivid to cross out the appropriate letters. This removed the problem of deciphering handwriting.

Observer: Time: Date:

Cow no.	Collar colour	0-10	10-20	20-30	30-40	40-50	50-60
123	G	G R I	G R I	G R I	G R I	G R I	G R I
126	G	G R I	G R I	G R I	G R I	G R I	G R I
127	Y	G R I	G R I	G R I	G R I	G R I	G R I
129	O	G R I	G R I	G R I	G R I	G R I	G R I
138	O	G R I	G R I	G R I	G R I	G R I	G R I
139	P	G R I	G R I	G R I	G R I	G R I	G R I
140	Y	G R I	G R I	G R I	G R I	G R I	G R I
141	O	G R I	G R I	G R I	G R I	G R I	G R I
146	G	G R I	G R I	G R I	G R I	G R I	G R I
147	Y	G R I	G R I	G R I	G R I	G R I	G R I
148	G	G R I	G R I	G R I	G R I	G R I	G R I
149	O	G R I	G R I	G R I	G R I	G R I	G R I
150	P	G R I	G R I	G R I	G R I	G R I	G R I
159	P	G R I	G R I	G R I	G R I	G R I	G R I
168	P	G R I	G R I	G R I	G R I	G R I	G R I
169	P	G R I	G R I	G R I	G R I	G R I	G R I
174	Y	G R I	G R I	G R I	G R I	G R I	G R I
176	P	G R I	G R I	G R I	G R I	G R I	G R I
178	P	G R I	G R I	G R I	G R I	G R I	G R I
181	P	G R I	G R I	G R I	G R I	G R I	G R I
185	P	G R I	G R I	G R I	G R I	G R I	G R I
188	P	G R I	G R I	G R I	G R I	G R I	G R I
190	G	G R I	G R I	G R I	G R I	G R I	G R I
194	O	G R I	G R I	G R I	G R I	G R I	G R I
195	Y	G R I	G R I	G R I	G R I	G R I	G R I
196	Y	G R I	G R I	G R I	G R I	G R I	G R I
198	O	G R I	G R I	G R I	G R I	G R I	G R I
200	G	G R I	G R I	G R I	G R I	G R I	G R I
207	O	G R I	G R I	G R I	G R I	G R I	G R I
208	O	G R I	G R I	G R I	G R I	G R I	G R I
213	Y	G R I	G R I	G R I	G R I	G R I	G R I
215	G	G R I	G R I	G R I	G R I	G R I	G R I
217	O	G R I	G R I	G R I	G R I	G R I	G R I
218	Y	G R I	G R I	G R I	G R I	G R I	G R I
219	Y	G R I	G R I	G R I	G R I	G R I	G R I
220	O	G R I	G R I	G R I	G R I	G R I	G R I
221	Y	G R I	G R I	G R I	G R I	G R I	G R I
222	G	G R I	G R I	G R I	G R I	G R I	G R I
223	P	G R I	G R I	G R I	G R I	G R I	G R I
227	O	G R I	G R I	G R I	G R I	G R I	G R I
228	G	G R I	G R I	G R I	G R I	G R I	G R I
229	G	G R I	G R I	G R I	G R I	G R I	G R I
234	P	G R I	G R I	G R I	G R I	G R I	G R I
235	G	G R I	G R I	G R I	G R I	G R I	G R I
241	O	G R I	G R I	G R I	G R I	G R I	G R I

Appendix 3.1 Recording sheet used for monitoring of grazing behaviour of lactating cows offered generous herbage allowances during June of 1998.

	Animal ID number																			
Ear Tag	194	180	208	226	201	181	218	219	246	196	129	166	207	221	179	182	243	205	234	172
Painted No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	234	
Time Interval:																				
10-20																				
20-30																				
30-40																				
40-50																				
50-01:00																				
01:00-01:10																				
10-20																				
20-30																				
30-40																				
40-50																				
50-02:00																				
02:00-02:10																				
10-20																				
20-30																				
30-40																				
40-50																				
50-03:00																				