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**EFFECTS OF FEEDING SILAGE AND EXTENDING
LACTATION ON THE PASTORAL DAIRY SYSTEM**

A thesis presented in partial fulfilment of the requirements
for the degree of Master of Agricultural Science
in Animal Science at
Massey University,
Palmerston North,
New Zealand

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1996

ABSTRACT

It is a common practice in the New Zealand seasonal dairying system to dry-off the herd at an earlier date in order to prevent excessive loss of body condition and average pasture cover. Thus, short lactation length is one of the main reasons for the low milk yield per cow in New Zealand. An experiment was carried out in April and May 1995 (54 days) at the Dairy Cattle Research Unit (DCRU), Massey University in order to measure the effects of extending the lactation, and feeding silage on the dairy farm system. On the 4th April, 54 of the lower yielding cows of the herd (118 cows) were dried-off and divided into two equal herds (D or control system). The remaining 64 cows were also divided into two equal herds, and milked for another 54 days (M system). Each of the four herds was grazed on a self-contained farmlet, at 2.9 cows/ha stocking rate. D herds received only grazed pasture (16 kg dry matter (DM)/cow/day allowance), while M herds received pasture (30 kg DM/cow/day allowance) plus silage (5.5 kg DM/cow/day). All of the replicated farmlets were feed budgeted to common targets of 2,000 Kg DM/ha pasture cover and condition score 5.0 at 29th May. At the end of the experiment the M system had produced 57.7 kg milksolids (MS, fat+protein) per cow, but had lower ($P < 0.01$) average pasture cover (by 584 kg DM/ha) and body condition scores (by 0.33 units/cow) than the D system. The target conditions were achieved by the D system, but not by the M system (deficits of 400 kg DM/ha pasture cover and 0.38 units CS/cow). When the feed required to overcome the deficits (when compared with the D system) in pasture cover and condition score of the M system was added to the silage fed, and these were all expressed in terms of their "pasture equivalences", a *total marginal response* to the silage feeding and extra days in milk of 116 g MS/kg equivalent pasture DM was calculated. Findings of this and previous farm system studies show that milk production response to late lactation (autumn) supplementary feeding is higher than was commonly believed, provided that it is associated with extra days in milk. Nevertheless, feed planning and management must be specially vigilant to ensure that the extended lactation does not cause reduced body condition score and pasture cover at the start of the next season.

ACKNOWLEDGEMENTS

I would like to express my special thanks to Associate Professor Colin Holmes, my supervisor, for his constant encouragement throughout my study. His time and efforts devoted to this experiment and also to my education are highly appreciated.

My special thanks are also given to Professor John Hodgson and Dr. Cory Matthew, of the Pastoral Group (Plant Science Department), for their advices and great contributions to my pastoral science understanding.

This work would not have been possible without the full involvement of Martin Chesterfield and Louise Platt from the Dairy Cattle Research Unit (DCRU). Thanks to both.

I would also like to thank the staff members of the Animal Science Department for their help and assistance. Particular appreciation to Drs. I.M. Brookes and G. Wilson.

Aderina, Mashudi, Hamsun and Wigati (Indonesian colleagues); Chandana, Min and Francis, all are gratefully acknowledged. Special thanks to Aderina Uli, Barbara Purchas, Nicolas Lopez and Jose Garcia.

My eternal gratitude to Joyce and Arthur Worboys, whose encouragement and support are invaluable. They are special persons for my family.

I would also like to gratefully thank to Jacky and Phill Mac'Donell, Claudia and Roger Clark and Ruth Hodgson, for their constant support given to my family.

My special thanks are given to the New Zealand Official Development Assistance (NZODA) Programme, for giving me the opportunity to undertake the study at Massey University, New Zealand.

To Universidad Nacional Agraria La Molina, Lima, Peru (my Alma Mater), for giving me the opportunity to continue my studies. Special thanks to Professor Guillermo Aguirre for his proud friendship, and *in memoriam* of Professor Alberto Pumayalla for his guidance and friendship.

Members of my family and relatives in my home country are gratefully acknowledged for their constant support and encouragement.

This thesis is dedicated *in memoriam* of Aurelia and Emilio, my parents, who would have loved to see this undertaking to be continued.

Finally, I would like to thank my wife Alicia and my children Paulo Cesar and Shaina for making my life so happy.

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LIST OF ABBREVIATIONS

A	Ayrshire
AHDMI	apparent herbage dry matter intake (kg DM/cow/day)
APC	average pasture cover (kg or t DM/ha)
BI	Breeding index
B_i	regression coefficient
BR	rate of biting (bites/min)
cm	centimetres
CP	Crude protein (%)
CS	cow body condition score (scale 1 to 10 units/cow)
CS Δ	condition score change
°C	Celsius degrees
D	Dried-off treatment
DG	Deferred grazing
DM	dry matter
DMD	digestibility of DM (%)
DOM	digestible organic matter (%)
DOMD	dry organic matter digestibility (%)
Eq.	Equation
FCE	feed conversion efficiency
g	grams
G	grazing activity
h	hours
ha	hectares
HDMA	herbage dry matter allowance (kg DM/cow/day)
HDMD	herbage dry matter disappearance (kg DM/ha)
HF	Holstein-Friesian
HM	herbage mass (kg DM/ha)
IVDDM	<i>in vitro</i> digestibility of dry matter (%)
J	Jersey
kg	kilograms

k_g	efficiency of utilization of ME for LW gain (%)
k_l	efficiency of utilization of ME for milk production (%)
k_m	efficiency of utilization of ME for maintenance (%)
l	litres
LC	Late control
LW	live weight (kg/cow)
LW Δ	live weight change
LW ^{0.75}	Metabolic size (kg/cow)
m	metres
M	Milked (plus silage feeding) treatment
M/D	Metabolisable energy content of the dry matter (MJ ME/kg DM)
ME	Metabolisable energy (MJ)
MF	milk fat
min	minutes
MJ	Megajoules
mm	millimetres
m ²	square metres
MP	milk protein
MS	milk solids (milk fat plus milk protein)
M-S	M treatment when silage was given
M-U	M treatment when silage was not given
n	number of observations
N	Nitrogen
NE	Net energy (MJ)
NH ₃	ammonia
ns	statistically non-significant
O	other (no feeding related) activities
OM	organic matter
P	Phosphorus
pH	Potential of Hydrogen
PGHM	pre-grazing herbage mass (kg DM/ha)
PMR	Plate meter readings

R	ruminating activity
R ²	coefficient of determination
RHM	residual or post-grazing herbage mass (kg or t DM/ha)
S	silage eating activity
s.d.	standard deviation
SD	stocking density (cows/ha)
s.e.	standard error of mean
sig	statistical significance
SR	stocking rate (cows/ha)
SSFR	Spring-summer fast rotation
t	test of Tukey
t	tonne
TADMI	total apparent dry matter intake (kg DM/cow/day)
TAMEI	total apparent metabolisable energy intake (MJ ME/cow/day)
vs	versus

CHAPTER ONE

INTRODUCTION

Dairy farming in New Zealand is primarily an export industry based almost entirely on the use of grazed pastures. The fact that New Zealand has considerable environmental advantages for year round pasture growth and outdoors feeding (grazing) have contributed to the development of a low cost efficient production system, which is renowned worldwide. This system is seasonal as determined by the pasture growth pattern, where the efficiency of production is a function of the amount of pasture growth, the efficiency of utilization and the feed conversion efficiency into milk products. Thus, efficiency of production, measured per hectare rather than per animal, is closely related to the farm's profitability.

In the seasonal dairying system, productivity per unit area is relatively high, but productivity per cow is low compared to overseas standards. The latter is a consequence of the short lactation length and the low daily milk yields. In fact, because of the seasonal pattern of feed supply, calving concentrates around late winter-early spring and cows are dried-off in early autumn before the slow pasture growth rates in winter, in order to avoid the carryover effects on subsequent milk production of the excessive losses in body condition score and average pasture cover. On the other hand, because farms are operated at high stocking rates in order to maximize pasture harvesting efficiency, most of the time cows can not be generously fed and consequently they can not meet their genetic potential.

In recent years New Zealand dairy farmers, researchers and consultants have become increasingly aware of the relatively low individual cow performance. Supplementary feeding has been suggested in order to lift production per cow. However, farm system (McCallum *et al.* 1995) evaluation of concentrate feeding has given uneconomic responses. Recent farm system studies (Clark 1993; Holmes *et al.* 1994; McCallum *et al.* 1995) have found high responses to supplementary feeding when it was associated with extra days in milk at later stages of lactation (autumn); which is contrary to what was commonly believed.

Extra days in milk in the latter stages of lactation are normally associated with loss of body condition score and in farm average pasture cover (Bryant 1978 and Holmes *et al.* 1994), which in turn are likely to affect the next season's performance. However, extra feed given in order to extend the lactation should produce a relatively high marginal response in extra milk produced, because all of the extra feed could theoretically be used for milk production.

The present experiment was designed to measure the effects of two systems of seasonal dairy farm management in late lactation: either drying-off (D), or continued lactation plus silage feeding (M), on milk production, body condition score and pasture cover, carried out as a duplicated farmlet system study during April and May, 1995.

Chapter Two of this thesis gives a brief description of the New Zealand dairy industry (Section 2.1), followed by a full review of the factors which influence the seasonal production system (Section 2.2), continued by a review of the main factors influencing the milk production response to supplementary feeding (Section 2.3), and finally (Section 2.4) a review of the range of late lactation feed supply alternatives.

CHAPTER TWO

LITERATURE REVIEW

2.1 The New Zealand dairy industry

2.1.1 Introduction

In New Zealand (NZ) about 2.8 million cows produce about 8,600 million litres of milk annually, which represents about 1.5 % of the world's production (LIC, 1995, FRST 1995). The dairying is located on about 1.1 million hectares of very productive flat to rolling country, located mainly in the North Island. Ninety-six per cent of NZ dairy herds supply milk for manufacture into dairy products, and are known as *factory supply* herds. The remainder supply milk for the domestic liquid milk industry (NZDB, 1993).

The entire NZ dairy industry has established itself through a vertically integrated structure, which works as a large co-operative. Dairy farmer shareholders elect their representatives as directors of the local manufacturing company and also of the New Zealand Dairy Board (NZDB). The NZDB works with the dairy companies to ensure their manufacturing programs match the demands of the international marketplace. It also integrates the industry's shipping, packaging, transport, storage and quality control needs, and provides necessary support services in the form of financial facilities, data processing, livestock improvement and administration (NZDB 1993).

The NZ dairy industry is based on the rural business of about 14,650 farmers, milking on average 193 cows on an 80 effective hectare farm at 2.5 cows/ha stocking rate (LIC 1995). For the 1994-1995 season the "average" farm produced 156 and 115 kg milkfat and milk protein per cow, respectively; the corresponding per hectare values being 386 and 285 kg, respectively for an average 208 days in milk (LIC 1995). These are equivalent to about 4 and 9 t pasture DM eaten per cow and per hectare, respectively (Holmes and Hughes 1993).

Approximately 94% of the milk produced is exported as value added milk products (950,000 tonnes), with a total annual sales of around NZ\$ 3.5 billion (19% of New Zealand's export income)(FRST 1995). The NZDB returns the net profits to the manufacturing companies, which in turn return the net profits to their farmer shareholders (NZDB 1993). Therefore, the price the farmer receives for his milk is almost entirely dependent on export prices and consequently returns to the NZ dairy farmer are considerably less than those in many other countries.

The milk payments scheme to dairy farmers is based upon the "A+B-C" system which incorporates payments for milkfat (A) and protein (B) with penalties for milk volume (C). According to LIC (1995), the average milk payout during the 1994/1995 season was NZ\$ 3.40/kg milksolids (MS, fat+protein), equivalent to around one third of what UK or USA dairy farmers actually receive (Bryant 1993).

The low prices received by NZ dairy farmers have determined the lower costs of production which must be achieved by NZ dairy farmers than those of their competitors. For example, it has been recently reported (ADRDC 1994) that on-farm milk production costs within the selected countries ranged from being the lowest in New Zealand (15 Australian c/l) through Australia, USA, Ireland, England to being the highest in the Netherlands (65 Australian c/l).

2.1.2 Principles

The tight financial constraints under which New Zealand dairy farmers must operate and the relatively favourable climatic conditions for pasture growth have determined that dairying must be almost entirely based on grazed pasture (Holmes and Hughes 1993). In fact, grazed pastures provide more than 90% of all feed required by herd; which results in reduced expenses in feed, labour, housing, equipment and health as compared to overseas drylot dairying systems (Holmes and Hughes 1993). This is why New Zealand dairy farmers are renowned worldwide as low-cost efficient milk producers (Murphy 1993).

To cope with the low cost of production, farmers must manage their farm operations and therefore the herd's feed requirements as closely as possible to match the seasonal pasture growth (Bryant 1993). Thus, all cows become pregnant in October and November, then calving is concentrated around July-September and they are dried-off before winter (April-May) (Holmes and Hughes 1993). Figure 2.1 (Holmes and MacMillan 1982) illustrates the matching of feed supply and feed requirements for a farm stocked at 3.7 cows/ha, cows calved on 1st August and dried off on 1st May, growing 13 t DM/ha annually.

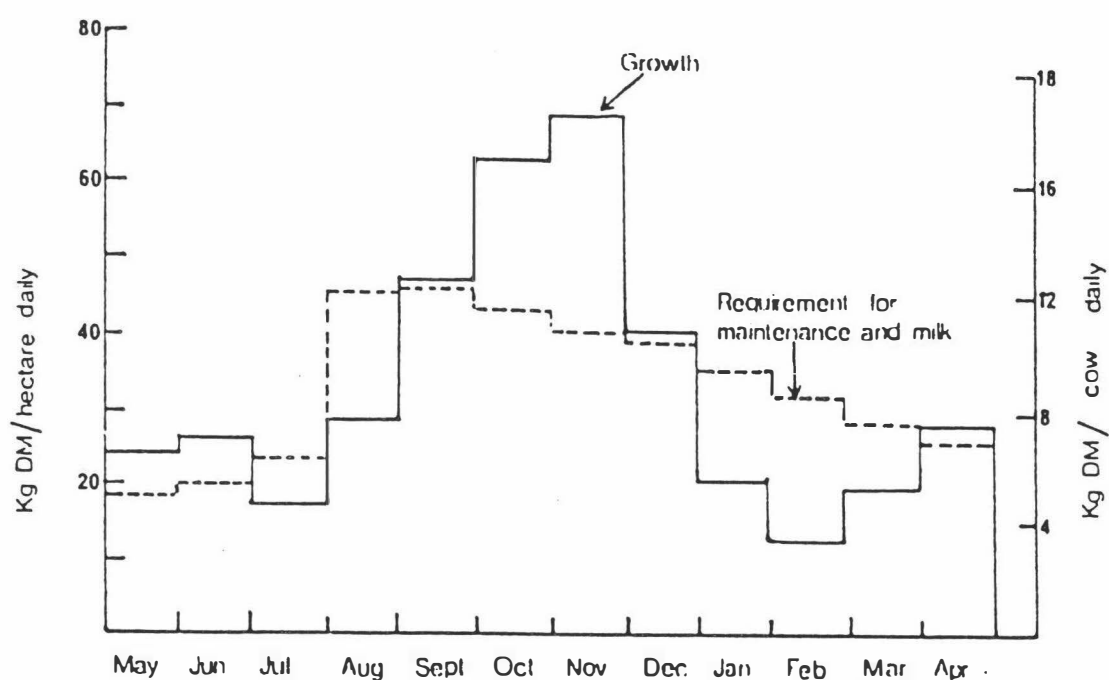


Figure 2.1: Feed supply and feed requirements matching for a seasonal dairy farm (3.7 cows/ha SR, cows calve on 1st August and dried off on 1st May) (Holmes and MacMillan 1982)

As a typical low input system, the profitability of New Zealand dairy farms is closely related to their productivity per hectare (Deane 1993; Murphy 1993). Therefore, the major determinants of farm productivity per hectare are how much pasture is grown, how efficiently this is harvested by the cows, and the feed conversion efficiency (FCE) of the cows (Bryant 1993; Holmes *et al.* 1993a).

2.1.3 Weaknesses

Because of its reliance on grazed pasture, New Zealand pastoral dairying system is associated with the following production weaknesses:

- 1.- The short lactation length (e.g. 208 days in 1994-95 season versus 305 days in overseas countries). The herd must be dried-off before winter in order to avoid excessive losses in body condition of the cows and average pasture cover on the farm, which may affect the next lactation performance. Then, pasture is saved during late autumn and winter in order to meet the minimum targets at calving.
- 2.- The low daily milk yield per cow. Partly because at the high stocking rates required to ensure efficient harvesting of the pasture, the cows can not be generously fed for most of the year (Bryant 1993; Holmes and Hughes 1993), and partly because pasture is not nutritionally balanced (Edwards and Parker 1994), cows can not meet their nutritional requirements to produce at their full potential. Recent studies (Peterson 1988) have revealed that New Zealand dairy cows are producing only around a half their genetic potential. Consequently, supplementary feeding and even ration balancing (Parker and Edwards 1994; Lean *et al.* 1995) are currently being promoted. Nevertheless, neither the technical nor economical merits of these approaches have been successfully demonstrated yet (McCallum *et al.* 1995, Penno and Carruthers 1995).
- 3.- Seasonally variable volume of milk available for processing. The extreme seasonality of milk production is reflected in the processing of milk. In general terms, about 50% of the milkfat is received by factories over 30% of the year, and less than a quarter of the total is processed during the off-season half of the year. Therefore, changes in the volume of milk supplied before or after the flush peak of the normal season, such as could be achieved by extended lactation, may increase the utilisation of plant and equipment and consequently decrease factory operating costs per unit of milk processed (McCombs 1986).

4.- Weather-associated risk. Effects of bad weather on pasture growth may be disastrous mainly at high stocking rates. In fact, prolonged very dry summers and cold-wet springs are common (Holmes and Hughes 1993).

2.1.4 Opportunities

Undoubtedly, on-farm feed supply is the main limiting factor to overcome the production weaknesses of the New Zealand dairying. However, any feed input should be assessed under the tight financial constraints of the system. For example, provision of extra feed at relatively low costs to overcome pasture deficits probably represents the best opportunity for profitable use of supplementary feeds, particularly if extra days in milk can be gained as a consequence; but, the break-even costs of feeds even under these conditions is unlikely to be much higher than about 0.06 (or 1/17) times the price per kg milksolids (Holmes *et al.* 1993b).

2.2 Factors affecting the seasonal dairying system

2.2.1 Introduction

As has been previously indicated, productivity per hectare is the main goal for dairying on grazed pastures; which has been recognized for many years to be determined by three key components of the system (McMeekan 1960; Holmes and Hughes 1993):

- (i) the quantity of pasture grown/ha;
- (ii) the proportion of the pasture grown consumed by the stock; and
- (iii) the efficiency of feed conversion into milk.

Thus, output from the system is in the first term determined by the potential pasture growth. However, the profitability of the system is closely dependent on the degree of success in coping with the seasonal variations in pasture supply

(Bryant 1990b). Then, the system may be manipulated through grazing management or stock policies. Stock policies involve a complex of variables such as stocking rate, genetic merit of cows, date and pattern of calving, drying-off date. On the other hand, grazing management policy involves controlling the rate of feed use, the timing, severity, frequency and duration of grazing.

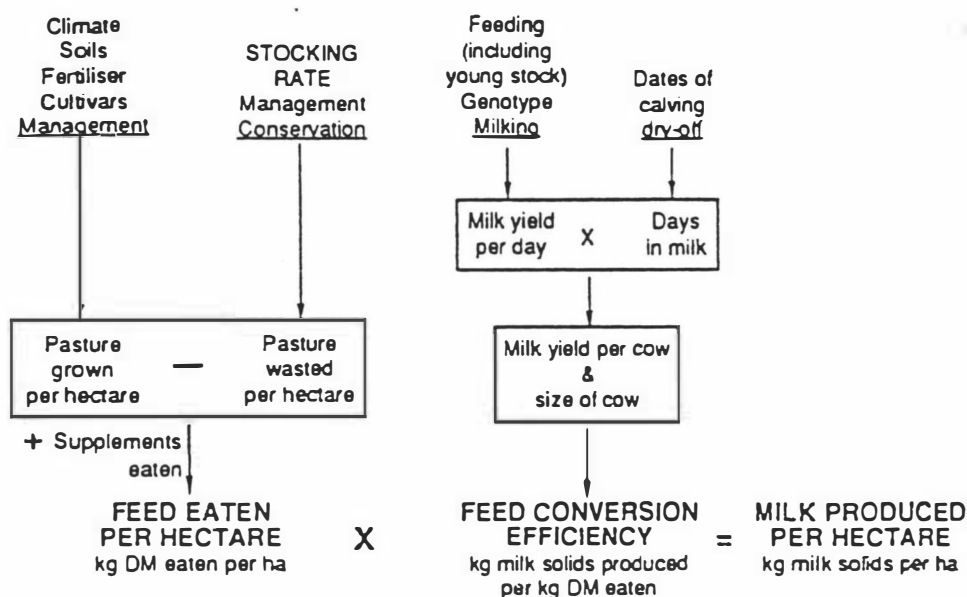


Figure 2.2: A simple model of the key elements of milk production per hectare, and of the factors which affect the key elements (Holmes 1990)

Figure 2.2 shows a simplified model of effects and interactions of some factors which influence production at a farm level (Holmes 1990). Of these factors, it has been recognized (McMeekan 1960; Bryant 1980a) that stocking rate has the dominant effect upon profitability per hectare. At the stage when the farm is stocked so that all pasture is eaten, with little wasted, then those factors which affect the farm's feed supply and the herd's feed conversion efficiency will assume crucial importance (Holmes 1990). Because of the resilience of both pasture and animals, it is generally agreed that stock policies are far more important than grazing management (Bryant 1990b).

2.2.2 Pasture production and utilisation

2.2.2.1 Pasture production

Pasture production is determined by the total pasture environment, which includes climatic factors, soil fertility, fertiliser, grazing management and pasture species. (Matthew 1992a). For a given location, temperature, soil moisture and soil fertility are the three major factors affecting the total annual pasture production. Soil fertility is the input factor most generally manipulated by dairy farmers, while the effects of grazing management on pasture productivity are much smaller than the effects of the any three major environmental factors (Matthew 1992a).

New Zealand dairy pastures contain predominantly ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) and they can produce up to 18 t DM/ha (Bryant 1983; Bryant and Holmes 1985); although it has been speculated that their potential production is up to 25 t DM/ha (Brougham 1959 cited by Hodgson 1989; Goold *et al.* 1985). However, Hodgson (1989) has pointed out that if the tissue senescence losses are discounted (20% minimum) from the indicated potential production, the theoretical maximum pasture accumulation is 20 t DM/ha, close to the upper values measured on North Island dairying areas. Thus, at least on the best farms, pasture yields are already approaching the local physiological and environmental potential known as the "feed barrier" (Hodgson 1989; Matthew 1992a).

Although the "feed barrier" problem is a cause of concern to a small proportion of the New Zealand farms, the seasonality of production of the conventional ryegrass/white clover pastures is a major problem of concern to all farms (Bryant and Sheath 1987). In fact, about 70% of the total growth occurs during spring and summer; whereas the corresponding autumn and winter growths are 20 and 10%, respectively (Bryant 1983). The seasonal pattern of pasture growth is reflected in the seasonal pattern of milk processing (Figure 2.3; Thomson and Holmes 1995).

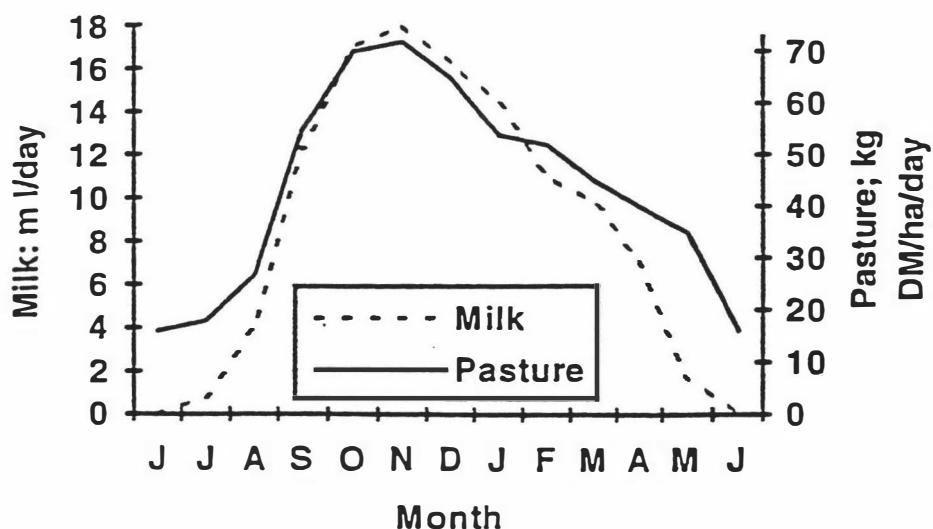


Figure 2.3: Daily milk flow (millions l/day) to factories in the Waikato region compared to the average pasture growth recorded at the DRC No. 2 Dairy (Ruakura) (Thomson and Holmes 1995)

2.2.2.2 Grazing efficiency

Annual grazing efficiency refers to the ratio of pasture consumed (grazed or conserved) per hectare annually to pasture grown per hectare annually (Holmes 1986a). Both pasture growth and consumption are most often estimated by the before- and after-grazing herbage mass technique. Therefore, because this procedure does not account for decay of herbage, it has been suggested (Bryant and Holmes 1985) that the harvesting efficiency estimated in this way will be always be close to 100%. On the other hand if the true growth is measured, the annual efficiency of grazing is likely to be between 50 to 70% in most of the New Zealand dairy farms (Bryant and Holmes 1985) and about 80-85% in the best managed farms (Smetham 1973 cited by Edwards and Parker 1994).

Grazing efficiency may be increased by any factor which increases annual herbage consumption such as higher stocking rate, larger cow size and higher level of milk production, and increased conservation. However it has been recognized (Holmes 1986a) that stocking rate is the most important single factor to increase the harvesting efficiency, with a decrease in senescence.

2.2.2.3 Gross efficiency of feed conversion

The gross efficiency of feed conversion on dairying systems is most commonly referred to the main product, milk. Gross efficiency of conversion can be described by the ratio of milk produced over the total herbage consumed, and values in the range of 35-45 and 30-35 g MF/kg DM (annually) for New Zealand and Victoria (Australia), respectively were reviewed by Bryant and Holmes (1985).

Undoubtedly, because the gross efficiency of conversion of an individual cow is inversely related to the proportion of its total feed requirements required for maintenance, the whole farm efficiency will be highly influenced by the stocking rate, the average size of cows and milk solids yield (Bryant and Holmes 1985).

Efficiency of feed conversion varies within the season as a consequence of the partition of nutrients eaten to milk production or to body weight gain. Thus, cows are most efficient in converting feed into milk during early lactation (Holmes and MacMillan 1982). Estimates of total feed conversion (immediate response plus carryover response) of 13, 15-24 and 22 for early lactation, late lactation and dry period, respectively have been reviewed by Holmes and MacMillan (1982).

Alternatively, when annual milk production of the farm is expressed in relation to the annual herbage grown on the farm, the overall farm efficiency of utilisation or productivity is estimated by the product of efficiency of harvesting and feed conversion efficiency (Bryant and Holmes 1985), which on an annual, per hectare basis is defined as:

$$\frac{\text{MilkProduced}}{\text{PastureGrown}} = \frac{\text{PastureConsumed}}{\text{PastureGrown}} \times \frac{\text{MilkProduced}}{\text{PastureConsumed}}$$

In general, high stocking rate increases the grazing efficiency, but causes associated decreases in conversion efficiency (higher maintenance costs per hectare) and per cow productivity (Bryant and Holmes 1985). Nevertheless, some "optimum" combination of stocking rate and general farm management decisions should maximise farm overall efficiency without substantial decrease in per cow production.

2.2.3 Grazing management

Grazing management has been considered as a fine tuning exercise (Bryant and Sheath, 1987), less important than pasture production, stocking rate, and stock policy. Bryant (1990a) has estimated that the effect of grazing management in per cow production does not account for more than 10 kg MF/cow. The role of grazing management may be limited to intensities of farming well above those that apply in common practice (Bryant and Sheath, 1987).

2.2.3.1 Grazing methods

Grazing management implies the use of grazing methods to feed the herd throughout the year. Grazing methods are generally grouped either as *continuous* or *rotational* and they are used to alter or control the rate of pasture use and the severity and frequency of grazing (Bryant and Sheath 1987).

Good grazing management involves the production of high yields of nutritious herbage over the grazing season and ensuring that the herbage produced is efficiently utilized by the dairy cow (Mayne and Thomas 1986). But, most importantly, grazing management is required to accumulate, transfer and allocate pasture from periods of surplus to those of deficit, or from times of low to those of high animal responsiveness (Bryant and Sheath 1987; Bryant 1990b). Then, controlled (rotational) grazing rather than continuous grazing fits best with these objectives (Field 1976), with the area or amount of pasture grazed each day being the manipulative tool to meet with these objectives (Leaver 1987).

Effects on pasture production and sward dynamics: Frequency and severity of defoliation can affect pasture production where pastures are cut (Bryant and Sheath 1987), but such effects are apparent for grazed pastures only in extreme conditions (Parsons *et al.* 1988; Hodgson 1990). The relative insensitiveness of grazed pastures to a wide range of grazing management has been attributed to the resilience of temperate species to buffer against changes in management (Bryant and Holmes 1985). For example at high stocking rates continuous grazing encourages the development of a dense sward with a very high population of small tillers, whereas rotational grazing results in a more open sward with much lower number of larger tillers (Evans 1981; Parsons *et al.* 1984 cited by Mayne and Thomas 1986; Leaver 1987; Hodgson 1990).

Effects on botanical composition: Common grazing methods have only small effects on sward composition, although clover is generally favoured by more intensive grazing (Bryant and Sheath 1987).

Effects on herbage intake: Herbage intake of grazing animals is the product of bite size, bite rate and grazing time (Burlison *et al.* 1991). Herbage mass or height during the grazing period is the most important characteristic of temperate pastures in this respect, through its effect on bite size (Leaver 1987; Hodgson 1986; Burns *et al.* 1994). Grazing method itself, has little effect on level of feed intake (Evans 1981; Leaver 1987) except through its effect on herbage mass and height (continuous grazing) or on pre- and post-grazing mass, or allowance (rotational grazing) (Bryant and Holmes 1985; Hodgson 1990).

Herbage intake by rotationally grazed dairy cows has been shown to be primarily influenced by herbage allowance (Combellas and Hodgson 1979; Le Du *et al.* 1979; Bryant 1980b), which effects are curvilinear of a diminishing returns nature, usually reaching a plateau at a daily DM allowance equal to 10-12% of the animal's body weight (Hodgson 1990). Since this allowance is between 2 and 3 times the maximum daily herbage intake, it involves a substantial wastage of herbage.

Pre-grazing herbage mass of rotationally grazed pastures has been shown to influence the herbage intake asymptotically (Combellas and Hodgson 1979; Meijs 1983), which declining incremental increases in herbage intake at higher HMs have been associated with a decrease in herbage quality (Baker *et al.* 1975; Hodgson and Jamieson 1981; Meijs 1981; Stockdale 1985) and change in the sward composition (Baker *et al.* 1975). However, it has been suggested (Combellas and Hodgson 1979) that herbage intake is not affected by PGHM within the range of 2-4 t DM/ha.

The stubble height remaining after grazing has been suggested (Le Du *et al.* 1979; Baker *et al.* 1981; Hodgson 1990) as a single sward description to assess the impact of sward conditions upon herbage intake and animal performance under rotational grazing management. Hodgson (1990) has suggested that the critical post-grazing stubble height for dairy cows grazing ryegrass-white clover pastures is approximately 10 cm.

Effects on animal performance: Grazing methods differ little in their effects upon animal performance (Bryant and Sheath 1987; Hodgson 1990). However at high stocking rates, both per cow and per hectare milk production are higher under rotational grazing than under continuous grazing (McMeekan and Walshe 1963; Campling 1976), even though grazing management effects are of less importance than the effects of stocking rate (McMeekan and Walshe 1963; Bryant 1990a).

2.2.3.2 Seasonal feeding management

Feeding management of grazing dairy cows is based on the balance of pasture growth and herd requirements throughout the year (Milligan *et al.* 1987; Stakelum 1993; Holmes 1995a). It implies planning in the long and short term (Milligan *et al.* 1987). Pasture growth rate is faster than consumption during late spring-early summer, but conversely it is lower than consumption during late summer and winter. Consequently, rational feeding of dairy cows involves the management of the deficits and surpluses most productively and profitably (Holmes 1995a).

The system is based on rationing of pasture consumption at maintenance levels during winter (low daily allowances) and consequently saving pasture until spring. Additionally, early calving is used to complete a greater proportion of the lactation before the summer decline in pasture growth. Consequently, average pasture cover at calving and in September are key factors in the success of this system (Clark *et al.* 1994). Undoubtedly, benefits of accurate feed rationing during winter and into early spring are greatest at high and inflexible stocking rates, and increase as winter pasture growth rates decrease (Bryant and MacDonald, 1983; Bryant and Sheath 1987). In general, pasture surplus can be managed by conserving either as silage, hay or on the paddock as deferred grazing; or alternatively "conserving" as extra body condition (Holmes 1995a). Undoubtedly any process of feed conservation is associated with some inevitable wastage.

Autumn-winter management:

Autumn-winter management should ensure enough pasture cover and, at the same time, reasonable cow body condition at the following calving (Bryant 1982; Bryant 1984; Holmes 1995a). Undoubtedly with high stocking rates and early calving both targets can not be simultaneously maximised, but other decisions such as grazing off-farm, supplementary feeding and N fertiliser application may help to achieve reasonable targets (Holmes 1995a).

Several authors (Bryant and MacDonald 1983; Phillips 1983; Thomson *et al.* 1993a) have stressed that winter management of the early calving herd should be primarily aimed to achieving increased pasture cover at calving. For example, it was estimated that at stocking rates of 3.5 to 4.2 cows/ha, and in the range of 1200 to 2000 kg DM/ha pasture cover, an increase of 100 kg DM/ha of pasture cover at calving caused an increase of 3 kg MF/cow (Bryant and MacDonald 1983).

Most of the amount of pasture present at calving is pasture saved as a consequence of intake restriction during the winter. Thus, the lower the daily

allowance the slower the rotation during winter, and the earlier in autumn this is established, the larger will be the amount of feed on the farm at the start of calving (Bryant 1990a). It has been suggested that 1 to 1.5 rotations during the 100 days of the dry period will provide a target cover at calving of about 2000 Kg DM/ha in Waikato conditions (Bryant 1990a).

Santamaria and McGowan (1982) have suggested that the increased pasture cover accumulated over autumn and winter as a consequence of intake restriction promotes extra pasture growth. However Parmenter and Boswell (1983) cited by Matthew (1992b) have shown that autumn-winter saved pasture results in increased senescence losses and losses of spring potential productivity. Reductions in grass tiller density and clover stolon density caused by high herbage masses following wintering-off were observed by Clark *et al.* (1994). In practice, the winter feed rationing has a bigger impact on the system than the potential growth probably lost; the benefits outweigh the disadvantages.

On the other hand, independently from whether a cow gained, lost or maintained weight before calving, cow condition at calving is another important factor affecting subsequent milk production and fertility (Rogers *et al.* 1979, cited by Grainger 1980; McDougall 1993). One extra kilogram of live weight at calving will result in an extra 0.29 kg milkfat (Bryant 1982). Alternatively, one condition score extra at calving (extra 30 kg liveweight in Jersey x Friesian cows) will cause an extra 4 to 11 kg MF/cow in the first 3 months of lactation and a quicker (6 days earlier) return to oestral activity (Grainger, *et al.* 1982). It was also reported (Grainger *et al.* 1982) that improved body condition at calving had a positive effect on milk fat percentage in early lactation.

From experiments carried out in Australia (Grainger and McGowan 1982) and New Zealand (Holmes and Grainger 1982; Bryant 1990a; Garcia-Muniz 1994), it can be concluded that to gain one condition score, a dry, pregnant dairy cow must eat around extra 150-170 kg pasture DM above maintenance requirements. Cows of 400 kg liveweight could gain 0.5 condition score in one month period if pasture

allowance is around 18 Kg DM/cow and eaten is around 11 Kg DM/cow (Holmes and McClenaghan 1980). Nevertheless, in the real situation generous winter feeding is rarely possible or practiced. Thus, because replacement during the dry period, of condition lost during lactation is expensive in terms of feed, Bryant (1982) has concluded that cow condition must be an important determinant of drying-off date (Bryant 1982).

Conflicting results of effects of rotation length during autumn-winter upon condition score and feed on farm at calving are reported by Bryant (1982). However a study involving farmlets (Gray and Matthews 1982) found no differences in subsequent milk production between a system in which fat cows (condition score 5.2) calved on low average cover (860 kg DM/ha) and a system in which thin cows (condition score 3.5) calved on high average pasture cover (1400 kg DM/ha) as a consequence of different autumn and winter feeding management.

It has been suggested that the effect of condition score at calving upon the subsequent milk production is less important than pasture cover at calving or in August (Bryant and MacDonald 1983) or level of feeding in early lactation (Grainger *et al.* 1982). Obviously, condition below a critical value (e.g. 4.5-5.0) would be disastrous not only for the subsequent milk production, but also for the subsequent mating performance. Therefore, considering the ability of the current dairy cows to recover from underfeeding in early lactation (by at least 35%)(Bryant 1990a), a compromise should be established to maintain a reasonable condition at calving, provided that average pasture cover in mid September will not fall below about 1700 Kg DM/ha.

Winter grazing for prolonged periods, particularly on heavy soils has been associated with pasture damage. Thomson *et al.* (1993a) concluded that block grazing and strip grazing respectively resulted in a 15 % and 27 % reduction in subsequent pasture growth compared with 4 hour "on/off" grazing; and long grazing periods (5-6 days) suppressed regrowth. On the other hand, Clark *et al.*

(1994) concluded that winter pasture residuals between 900 and 1800 kg DM/ha, but achieving the same average target cover at calving (2000 kg DM/ha) had no consistent effects on subsequent pasture productivity or milk yield. Computer simulation has shown that wintering-off can lead to increased milk production when the average pasture cover in September is predicted to fall below 1750 kg DM/ha in the absence of the winter grazing-off (Clark *et al.* 1994).

Early spring management:

Early spring grazing management is highly dependent on pasture growth rate and pasture cover at calving. Pasture cover in this period should be maintained above a minimum (e.g. about 1,700 kg DM/ha) by a gradual increase in herbage allowance as the growth season progresses (Penno 1993; Holmes 1995a). Bryant and L'Huiller (1986) have concluded that in a bad spring (< 45 kg DM/ha/day growth), the combination of a low cover (<1.4 t DM/ha) and fast rotation (8 days) will be disastrous for subsequent milk production.

The above implies that there must be a compromise between maintaining the mid September pasture cover and underfeeding the cows very early in lactation (Bryant 1990). Cows are able to recover from this modest feed restriction provided that pasture cover in mid September does not fall below the critical levels (1700 Kg DM/ha). Dairy farmers who achieve high feed cover at calving will usually be able to maintain a reasonable cover in this period.

Late spring-early summer management:

During the late spring and early summer, daily growth rate may be 10 to 40 kg DM/ha faster than the daily pasture consumption rate, even when herd is generously fed (Holmes, 1995). Therefore, grazing management in this period must be devoted to controlling surplus growth, which is associated with the reproductive phase of pasture (Bryant 1990a).

Application of increased grazing intensities in order to control pasture growth and quality on some of paddocks, and conserving ample amounts of silage or hay on the remaining shut-up paddocks to meet subsequent deficits are the common practices on most of the dairy farms in New Zealand (Bryant, 1990a; Holmes 1995a). However, these conventional practices are associated with restricted levels of feeding and high costs associated with forage conservation. Opposed to this conventional management, alternative approaches have evolved in order to manipulate the flush of pasture growth and the subsequent pasture persistency. These are: spring-summer fast rotation, late control and deferred grazing.

The *spring-summer fast rotation (SSFR)* approach proposes high intensities of grazing and fast rotation (about 5-day) in order to encourage vegetative tillering and tiller survival (L'Huillier, 1987a,b,c, 1988). Compared to conventional 30 days-round rotation, the advantages of SSFR are the production of good quality herbage and reduction of senescence (Hoogendoorn *et al.* 1985). However, although milk yield in spring may be improved, SSFR cows lose condition score due to pasture shortage in summer. Consequently, SSFR herds need to be dried-off earlier in order to protect condition score and pastures going into winter (Anonymous 1990, 1991, 1992).

The *Late control (LC)* approach implies a deliberate encouragement of reproductive growth of pastures in spring in order to promote the development of the maximum potential of grass tillering and to obtain high pasture growth rates associated with reproductive phase in late spring (Matthew, 1991). It was found (Hernandez-Garay *et al.* 1993) that lax defoliation prior to and during the reproductive phase followed by later hard grazing (late November) favours vigorous tillering in early summer and improves summer-autumn pasture growth and persistence, which have been associated with increased milk yields in this period (Da Silva *et al.* 1994).

Alternatively, *deferred grazing (DG)* is the practice of preserving *in situ* the pasture considered surplus, to be grazed at a later date when shortage of pasture

occurs, usually in summer/autumn (Thomson 1989; McCallum 1991; McCallum *et al.* 1991). DG is not only a cheap way for pasture conservation but it may also help to renovate the pasture by natural reseeding, provided that seedling establishment is appropriately managed (McCallum *et al.* 1991).

Late summer-early autumn management (see also Section 2.2.4.3):

Pasture growth rate during a very dry summer can be around 10-30 kg DM/ha/day lower than the daily rate of feed consumption, which would cause pasture cover to decrease by around 300-900 kg DM/ha/month (Holmes 1995a). Holmes (1991) cited by Holmes (1995a) estimated that a direct effect of dry summer on milk production would be around 7 to 14 kg MF per cow. Furthermore, the carryover effects after a dry summer can be a decrease of around 1 kg MF/cow in the following season, associated with each 4 kg MF/cow immediate decrease in the dry summer (Scott 1978 cited by Holmes 1995a).

Condition lost during a dry summer can be replaced during winter when the cows are dry, requiring an extra 150 kg DM to increase condition by one score (Bryant 1990a). Unless wintering-off, at high stocking rate this expense must be avoided if the targets at calving for condition score (minimum 4.5-5.0) and average pasture cover are to be achieved. Avoiding this expense involves preventing cow condition getting lower than a score of 4.5 in late lactation (Bryant 1990a). Early culling, which is associated with reduction in herd's feed requirements appears be much more effective in achieving this rather than an early drying off (Bryant and MacDonald 1987; Bryant 1990a).

Most commonly, feeding levels in late lactation are restricted, but few studies have evaluated the effects of different levels of pasture feeding on milk production at late lactation. Milk production response to successive increments in feeding level is curvilinear; then absolute intake levels and therefore differences in feeding levels will influence the marginal response (Wilson and Davey 1982). For example, estimates of marginal response in the range from 11 to 30 kg extra MF/t

extra pasture DM have been reviewed by Wilson and Davey (1982). In turn Holmes *et al.* (1987) have quoted a total (adjusted by liveweight change) marginal responses between 51 and 63 kg MF/t DM, with high BI cows having higher efficiencies than low BI cows.

Alternatively, effects of dry summers can be counteracted by supplements such as summer forage cropping and also by an earlier calving date, so that more days in milk can be gained before the dry weather. Similarly, in late summer, early drying off or grazing-off should be considered in order to protect next seasons production (Holmes 1995a). As the dry weather continues and milk yield declines, milking once a day may be adopted, it will cause little further reduction in milk yield, but it will not alleviate feed shortage (Bryant and MacDonald 1987). Thus, although use of supplements may allow some extra days to be gained in late lactation (Clark 1993), most importantly the management in this period must be devoted to protect next season milk production by avoiding excessive losses in body condition and pasture cover.

Dry off date is the most important tactical management decision made in this period. It is covered in detail in the next section.

2.2.4 Stock policies

2.2.4.1 Stocking rate

Stocking rate (SR), the link between pasture and animal components, has been conventionally defined as the number of animals per unit area for a substantial period of time (Hodgson 1990). Nevertheless, because this definition does not account either for the productive potential of pasture or for the potential herbage intake of the herd (Hodgson 1990), Holmes and Parker (1992) have alternatively suggested the term "effective SR", defined as a relation between the total pasture eaten and the total pasture growth per hectare and per year basis. SR affects pasture and animal production by its direct effect on grazing intensity (Figure 2.4)

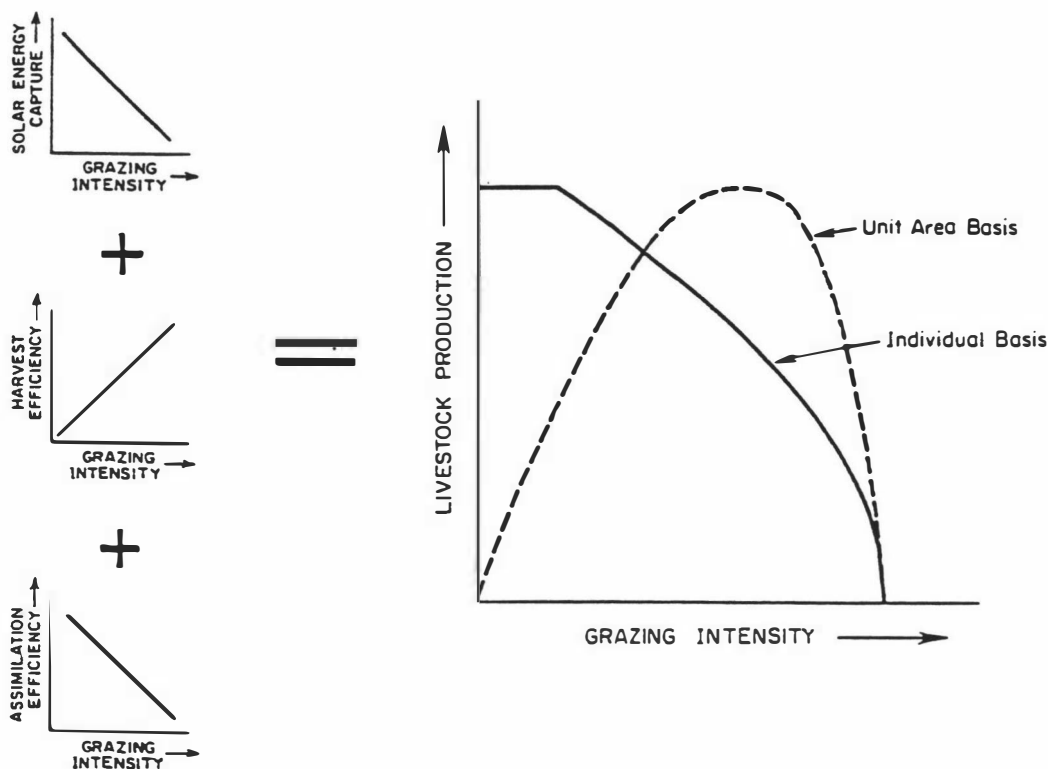


Figure 2.4: Per animal and per unit area livestock production resulting from the combined effects of solar energy capture efficiency, forage harvest efficiency, and conversion efficiency in response to grazing intensity (Briske and Heitschmidt 1991)

Effects on pasture production, composition and quality:

Both overstocking (McMeekan and Walshe 1963; Stockdale and King 1980) and understocking (White 1987) negatively affects pasture growth. The main factors responsible are the reduced availability of photosynthetic tissue in the former case and the greater abundance of less efficient photosynthetic tissue and increased senescence in the later (White 1987; Hodgson 1990). However, seasonal changes in this general pattern have been reported by Campbell (1966a,b). Reduction in pasture production, can also be associated with the increased soil bulk density observed at high stocking rates (Humphreys 1991).

White (1987) suggests that high SRs often reduces the proportion of palatable species in the pasture and that due to the reduced pasture cover, weed species can invade the system. On the other hand, other authors (Brougham *et al.* 1978 cited by Stockdale and King 1980; Stockdale and King 1980; Holmes and MacMillan 1982) have indicated that high SRs promote high clover content by reduction of the shading effect of erect grasses.

It is generally accepted that increasing SR is likely to have a positive effect on pasture quality (Holmes *et al.* 1987). In fact, at high SRs, the digestibility of the available herbage is raised as an highly digestible leafy pasture with reduced proportion of dead material is obtained (Stockdale and King 1980; Baker and Leaver 1986). On the contrary, low SRs are associated with reduced digestibility in herbage available, although selective grazing can compensate for this effect (Hodgson 1990).

Effects on herbage utilization and intake:

The effects of stocking rate on efficiency of pasture utilization and consequently on the overall farm productivity are overwhelming (McMeekan and Walshe 1963; McMeekan 1964; Bryant 1980; Hodgson 1990). Harvesting efficiency increases as SR increases. For example, when disappearance by decay is take into account, annual per hectare herbage utilization between 50% (at low SR) and 70% (at high SR) have been estimated (Stockdale and King 1980; Bryant and Holmes 1985). However, high SRs have adverse effects on daily herbage intake per cow (Stockdale and King 1980; Holmes and Parker 1992). For example, McMeekan (1964) indicated that high-stocked (3.2 cows/ha) cows ate 10% less DOM/cow/day, but they harvested 41% more DOM/acre/day that cows at low SR (2.0 cows/ha). It was found (McMeekan and Walshe 1963) that at high SRs, rotational grazing performed better (+8%) in its effects on pasture utilization and output per hectare than continuous grazing.

Effects on animal performance:

As shown by Figure 2.4 (Briske and Heitschmidt 1991), there is an inverse relationship between individual animal performance and output per unit area. The increased output from high SRs occurs because of the increase in total harvesting efficiency and DM eaten/ha, and despite the decrease in DM eaten, milk yield and feed conversion efficiency per cow (McMeekan 1964; Bryant and Sheath 1987).

In the short-term, SR affects cow performance through its influence on daily herbage allowance (Baker and Leaver 1986); as SR increases, animals compete for the available herbage, selectivity decreases, then insufficient quantity and quality of herbage is ingested, which will decrease individual animal performance (Hodgson 1990). If SR increases further, the availability of forage for maintenance requirements, and body condition of the animal decreases (Humphreys 1991).

Holmes and Parker (1992) have summarized the basic relationships between intake animal performance and conversion efficiency as affected by stocking rate. They used data collected (1982-1985) at Ruakura Research Station involving Jersey cows and 16 t DM grown/ha. Thus, when SR was increased from 2.75 to 4.28 cows/ha, the intake per cow/year decreased 18%, whereas the intake per hectare increased 29%. Similarly, both milk fat and milk protein yield per cow decreased about 25%, but yields per hectare of these products increased 15% even though the efficiency of feed conversion decreased by 10 and 7% for milk protein and milk fat, respectively. At dry-off, high SR cows scored 3.9 body condition, whereas low SR cows scored 4.6. These decreased condition scores at drying-off and at calving achieved by high-stocked cows (McMeekan and Walshe 1963; King and Stockdale 1980; Holmes and Parker 1992; McDougall 1993) may affect the subsequent mating performance.

2.2.4.2 Calving date

Calving is associated with 50 to 100% increase in feed requirements, whereas drying-off is associated with reduction in feed requirements of a similar magnitude. Therefore, these events can be manipulated in order to match feed supply and feed demand (Holmes and MacMillan 1982).

On seasonal dairy production systems, the matching of calving date to the start of the new grazing season is an important decision and implies not only prediction of pasture growth and feed profiling for the next season, but also mating management (Holmes and MacMillan 1982; Dillon and Crosse 1994). Although calving in late winter-early spring is a major general decision, this date can still be manipulated to some extent in relation to the onset of rapid pasture growth in spring, which will influence the level of feeding in early lactation (i.e. earlier or later) as well as the duration of the lactation period (Holmes and MacMillan 1982). In general, within a herd, early calving cows are likely to have longer lactations but they may be underfed in early lactation, causing a lower average daily milk yield; whereas, later calving cows are likely to have shorter lactations but although they are likely to be well-fed in early lactation, they are likely to conceive late and therefore they will be late calvers again next year (Holmes 1995b).

The calving pattern of a herd has a skewed distribution; then, the temporal distribution of calvings from the planned start of the calving season rather than mean calving date provides a more useful description of the calving pattern (Holmes and MacMillan 1982; Crosse *et al.* 1994). For example, according to MacMillan *et al.* (1990) in the Waikato region, the average calving season was around 11 weeks (without induction), but 50% of cows calved within the first 3 weeks after the start of calving (1st August).

It is generally agreed that an early and compact calving (i.e. all cows calving within 6-7 weeks period) has a large influence on profitability and is easy to

manage (Crosse *et al.* 1994; Short 1995). For example, Deane (1993) has reported that in studies at Ruakura, compact calving herds had between 8 and 16 more days in milk before Christmas than the normal calving herds and production per cow increased by 0.87-1.00 kg milkfat over the whole herd for every extra day in milk before Christmas. The achieving of a early compact calving pattern implies high submission rates and also a subsequent well planned early spring feed supply. In turn, achieving high submission rates requires good health and good pasture supply (e.g. pasture cover above minimum 1800 kg DM/ha) at the time of peak milk yields and mating (Short 1995). Currently available controlled breeding techniques can help to achieve these goals (MacMillan 1993).

High stocked, early and compact calving herds have been associated with underfeeding at early lactation (Bryant 1989; Holmes 1986b). Milk production lost as a consequence of this underfeeding may be compensated by a longer lactation length (Bryant and MacDonald 1983; Holmes 1986b). However, in the absence of supplementary feeding, a herd which calves too early can not always compensate by a longer lactation (Holmes 1986b). On the other hand, total milk production from herds which calve too late may be reduced due to the short lactation length.

Additionally, Bryant (1989) showed that the seasonal milk supply to factories can be slightly modified by early calving date. In fact, production was shifted from the peak and post-peak periods into the pre-peak period.

2.2.4.3 Drying-off date

Drying off date is an important management decision, especially on high stocked farms because it determines the feed required in summer-autumn, the farm pasture cover and the cows body condition at the end of lactation (Bryant 1981). Consequently, it also determines the feed needed to improve condition score prior to the next calving and the status of feed reserves at calving (Wilson and Davey 1982). This decision will contribute to the success of next season's milk

production and reproductive performance. Bryant (1984) has indicated that the main facts influencing drying off decisions are the evident greater proportion of dietary energy diverted to body condition gain at late lactation (higher in low BI than in high BI) and the necessity for saving feed by culling and by the reduced requirement of dry cows. However, exceptional pasture growth at autumn can delay drying off date.

A recent survey (Parker *et al.* 1995) about drying off management on seasonal dairy farms carried out in 3 regions of North Island (Northland, Waitoa and South Taranaki) and 2 regions of South Island (West Coast and Southland) has revealed that the majority of farmers (70%) dried the herd off in stages rather than all at once. Thus, first calvers or older cows in low condition with poor milk production were dried off early. However the main reasons (in order of importance) for the drying off decision were the availability of pasture, or the availability of pasture plus cow condition, or weather conditions and the level of per cow milk yield. In the two South Island regions, the last day of milk collection by the company was another important reason for dry off date.

Holmes and MacMillan (1982) have summarised (using data from Ruakura) the effects on body weight and pasture cover of 3 weeks extra days in milk for cows fed on restricted amounts of pasture. During this period each cow produced 7.4 kg milkfat, lost 7.6 kg LW and consumed 158 kg pasture DM. If they had been dried off 3 weeks earlier, they would have produced no milk, lost no weight and consumed only 120 kg DM. However, whether the 7.6 kg extra liveweight and the 38 kg pasture DM saved by early drying-off would compensate for the 7.4 kg MF or not will depend of the dry-off period management.

According to the drying-off management survey (Parker *et al.* 1995), targets of pasture cover and condition score at drying off were respectively on average 334 kg DM/ha (1795 vs 2129 kg DM/ha) and 0.70 (4.6 vs 5.3) lower than those specified for the commencement of calving. Undoubtedly, winter grazing-off or supplementary winter feeding are required to cope with these targets. On the other

hand, according to the same survey, pasture availability at calving followed by cow condition at calving was rated by the farmers as having the largest influence on early lactation milk production, whereas drying off date received the lowest rating. Nevertheless, both pasture reserves and cow condition at calving are heavily influenced by drying off date.

In the most recent season (1994-1995) the average days in milk of New Zealand dairy herds was 208 days (LIC 1995), which is extremely low compared to the standard 305 days of the overseas non-seasonal systems. Taking into account the fixed costs of maintenance of cows, dry or lactating, late lactation offers good scope for extra milk production with a good marginal response from extended days in milk if extra feed is given at this stage (Holmes and Brookes 1993). Wilson and Davey (1982) have suggested that because high BI cows divert a greater proportion of energy intake towards milk, they may be more responsive to extra feed in late lactation than low BI cows. In fact, recently, benefits of extra days in milk from extra feed produced by nitrogen fertiliser (Harris *et al.* 1994; Penno *et al.* 1995) and silage (Clark 1993) have been shown.

2.2.4.4 Breed and genetic merit of cows

The breed composition of the New Zealand dairy herd is currently 57% Holstein-Friesian (HF), 18% Jersey (J), 16% Holstein-Friesian/Jersey (HFJ), 2% Ayrshire (A) and 7% other breeds (LIC 1995). In the 1994/1995 season, on average HFJ cows produced more milkfat (167 kg) than the other breeds, followed by HF cows (161 kg) which also produced more protein (126 kg) and milk volume (3628 l) than the other breeds. For the same period, Jersey cows accounts for the highest milkfat (5.86%) and protein (4.16%) tests (LIC 1995).

Breeding Index (BI) measures the genetic merit of cows and bulls in New Zealand, which is based on ancestry and individual cow herd test information (LIC 1995). For the 1994-95 season the average herd BIs of herds tested was 135, 124 and 128 for milkfat, protein and milk volume, respectively (LIC 1995).

The average milkfat yield of New Zealand dairy cows was 156 kg/cow during the last season (LIC 1995), far from the 240 kg achieved on overseas (Pennsylvania) under high input systems (Parker and Muller 1992). Recent studies (Peterson 1988; Graham *et al.* 1991) in which the daughters of Canadian and New Zealand sires were reared and milked in Canada or New Zealand have revealed that milk yield of New Zealand cows is not limited by their genetic potential, but by the relatively low levels of feeding which are achieved at current stocking rates. It has been concluded that under the cost and prices which prevail in New Zealand, feeding to achieve genetic potential is unlikely to be most profitable (Holmes *et al.* 1993a).

Studies at Massey University with Holstein-Friesians (Grainger *et al.* 1985) and Ruakura with Jerseys (Bryant 1984) have shown that high BI cows produce more milk and are more efficient convertors of feed into milk, but they lose more body condition than lower BI cows. For example, in the experiment at Ruakura, at 4.3 cows/ha high BI cows (125 BI) produced 27% more milkfat (680 vs 535 kg milkfat/ha), but at dry-off they were thinner than low BI cows (100 BI) (Bryant 1982, 1984).

Bryant (1984) has suggested that the relative superiority of the HBI cows is due mainly to their higher daily milk production and food intake, longer lactations, greater feed conversion into milk, better grazing ability and better ability to recover from periods of underfeeding. Furthermore, it has been recognized that this superiority of the high BI cows becomes greater as lactation progresses (Holmes and MacMillan 1982). Thus, high BI cows have more potential to extend in their lactation than low BI cows, but a higher level of feeding during the dry period will be necessary if these cows are to regain their greater lost condition (Holmes and MacMillan 1982).

Although large genetic differences have been observed for gross energetic efficiency (energy in milk/energy in food), it is still difficult to identify the sources of variation with any confidence (Veerkamp and Emmans 1995). These

authors have suggested that these sources are likely to be milk yield, the capacity for feed intake, the extent to which body tissue is mobilised and any differences in partitioning the energy eaten between maintenance, lactation and body tissue gain or loss. It has been suggested (Holmes and Macmillan 1982; Veerkamp and Emmans 1995) that high genetic merit cows are more efficient because they partition the available energy differently from low genetic merit cows, and not because the processes used to transform consumed feed into valuable product have become more efficient.

2.3 Milk production responses to supplementary feeding

2.3.1 Principles and measurements of responses to extra feed

Figure 2.5 is a simplified model which illustrates the principles of milk production responses to extra feed. In general terms, the marginal response (kg extra milk/kg extra feed) will depend on (i) the amount of nutrients which must be utilised for other essential purposes (e.g. maintenance, growth, pregnancy), and (ii) the amount of feed wasted as a result of the extra feed. Therefore, efficient management systems which minimise these sources of "leakage" will maximise the response to extra feed, and will enable economic responses to be achieved with relatively more expensive feed inputs (Holmes 1995c).

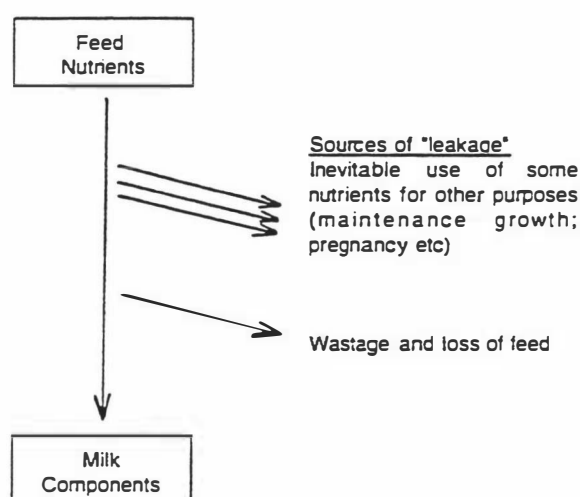


Figure 2.5: Model of principles of milk responses to extra feed (Holmes 1995c)

Milk production responses to supplementation can be measured in different ways. Most importantly, because of the dynamic nature of factors which influencing responses to supplements, measurement of the long-term effects on the whole-system appears be most relevant for any practical recommendations. In general, the response is measured in terms of *marginal response*, i.e. the increase in milk production due to extra feed input, the size of which usually decreases as the quantity of input increases.(Kellaway and Porta, 1993). The marginal response can be measured as an *immediate response*, i.e. the increase in milk production soon after introducing a supplement, or as *total response*, i.e. the immediate response plus the residual effects (after the supplementary feeding has ceased) of the gained (or lost) body condition score, pasture cover and fertility. Holmes (1986a) has suggested that the consumption of an additional 11 MJ ME from a supplementary feed should theoretically cause : (a) the production of an extra 90 g milkfat, or (b) an increase of liveweight by 300 g, or (c) a decrease of 11 MJ of ME in the cow's intake of grazed herbage, or (d) some combination of a, b and c.

2.3.2 Factors affecting milk production response to supplementary feeding

The major factors affecting the response of cows to supplementary feeding are depicted in Figure 2.6. All these factors interact with each other and not only affect the immediate response, but also the subsequent production (Rogers 1985).

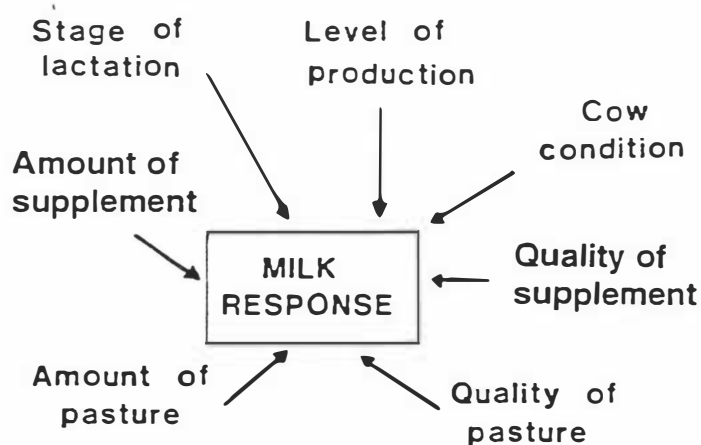


Figure 2.6: Factors affecting the milk production response to supplementary feeding (Rogers 1985)

2.3.2.1 Effect of stage of lactation

The size of the immediate response in milk production to supplementation is greatest in early lactation, because the proportion of feed energy partitioned towards milk production decreases as lactation progresses (Broster and Thomas 1981; Trigg *et al.* 1983). For example, a series of stall fed experiments conducted by Stockdale *et al.* (1987) have shown marginal responses of 1.3 and 0.7 kg milk/kg DM concentrate in early and late lactation, respectively; whereas the response to maize silage supplementation under similar conditions were 0.89 and 0.63 kg milk/kg DM (Stockdale 1995). Nevertheless, partition of nutrients is not considered in the major systems used to calculate nutrient requirements for dairy cows, because of the difficulty for its prediction (Hulme *et al.* 1986; AFRC 1993).

Average immediate responses by grazing cows were 0.6 and 0.5 kg milk/kg concentrate in early and mid-late lactation, respectively, as reviewed by Kellaway and Porta (1993). However, surprising responses to supplementary feeding in autumn have been recently reported in New Zealand (Clark, 1993) and Ireland (Stakelum *et al.* 1995). Clark (1993) found that the immediate response of autumn silage feeding (50 g MS/kg DM silage) was 2 and 3 times greater than that observed for spring and summer silage feeding, but condition score was depressed by 0.3/cow, whereas pasture cover was maintained. In the experiment reported by Stakelum *et al.* (1995), the response in milk production was 0.95 kg milk/kg concentrate in autumn; whereas the corresponding responses in spring and summer were 0.2 and 0.4, respectively.

Long term responses to supplementary feeding have also been assumed to be greater in early lactation because of the higher requirements of the cows (peak of lactation) and also the substitution effect should increase total farm pasture cover (Rogers 1985; Kellaway and Porta 1993). However most of the early lactation supplementary feeding (meal, hay or silage) trials in New Zealand and Australia reviewed by Bryant and Trigg (1982) failed to show large long term responses (carryover effects were about a half the immediate responses).

2.3.2.2 Effect of body condition score

Milk production response to supplements is affected by the cow's condition score at the start of supplementary feeding and also by the changes in body condition as a consequence of supplement feeding (Kellaway and Porta 1993). Grainger *et al.* (1982) showed that for a given level of feeding, milk production is directly related to condition score. The higher the cow's body condition score (in the range 3 to 6) when beginning to feed supplements, the greater the apparent response to the supplement, because of partitioning of body tissue energy towards milk production (Kellaway and Porta 1993). On the other hand, supplements allow animals to increase milk production and to gain more condition or lose less condition than unsupplemented animals. Hamilton (1991, personal communication) cited by Kellaway and Porta (1993) showed that cows having a condition score of 4 partition energy to liveweight gain. As their body condition improves (from 5 to 6), they start to partition more energy to milk production, increasing the milk response to the supplement. However, this pattern may be influenced by the genetic merit of cows (Holmes *et al.* 1985).

2.3.2.3 Effect of substitution

Generally, when supplements are fed to grazing animals, pasture intake is depressed. Consequently, the total increase in DM intake is less than the additional amount of DM supplied by the supplement. This phenomenon is known as *substitution*, which is defined as the decrease in pasture intake per kg supplement eaten on a DM basis (Grainger and Mathews 1989) and is the main reason for the large variation observed in responses to supplementation (Grainger and Mathews 1989; Kellaway and Porta 1993)). Rates of substitution in the range 0.3-0.9 have been reviewed by Kellaway and Porta (1993).

Pasture allowance, herbage quality, and type and level of supplement are the main factors affecting substitution rate. Grainger and Mathews (1989) found that at 7.6 Kg DM/cow/day herbage allowance, concentrate feeding (3.2 kg grain-based

pellets/day) did not affect pasture intake, but when pasture allowances were increased to 17 and 33 kg DM/cow/day, substitution rates of 0.25 and 0.69 were calculated. The milk production responses to concentrate feeding at the 3 levels of pasture allowance were 0.97, 0.69 and 0.28 kg milk/kg DM, respectively.

Studies involving various levels of supplementary feeding (grain pellets) at different herbage allowances (Meijs and Hoekstra 1984; Stockdale and Trigg 1985) have shown greatest substitution at the highest herbage allowance and level of supplement (Figure 2.7); whereas, at low herbage allowances, substitution only occurred at the highest concentrate level. Contrarily, Stakelum (1986) reported that concentrate feeding depressed herbage intake with no interaction with herbage mass or herbage allowance.

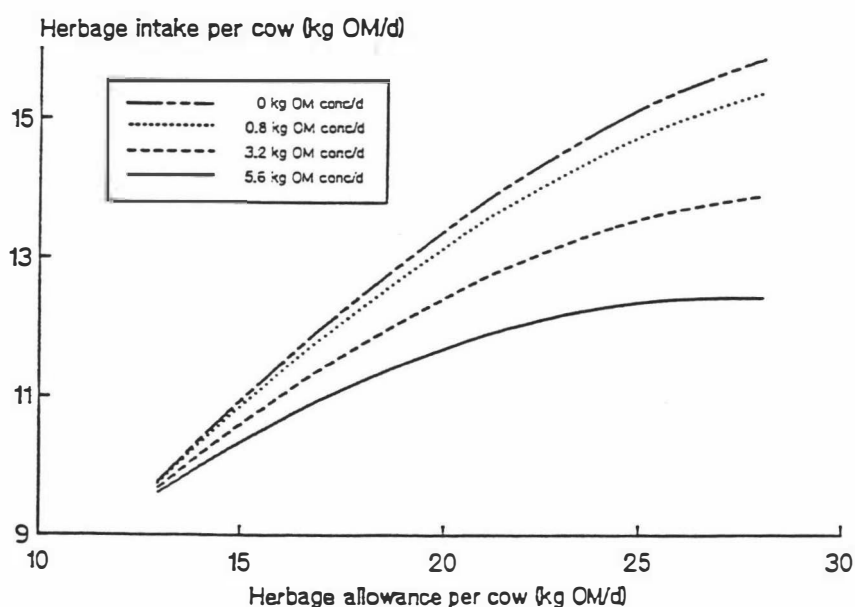


Figure 2.7: Effect of herbage allowance on herbage intake at different levels of concentrate feeding (Meijs and Hoekstra 1984)

Huston and Pinchack (1991) have suggested that on low to medium quality herbage (<55 DMD and 6% CP), no substitution (i.e. effective supplementation) may be expected. On the contrary, where there is opportunity for selective grazing (Mayne and Wright 1988) or where quality of herbage is improved (e.g. high clover content) (CSIRO 1990; Wilkins *et al.* 1994), greater substitution rates have been observed.

Meijs (1986) and Dillon *et al.* (1989) have found that highly digestible fibrous concentrates such as beet pulp resulted in lower substitution and higher milk production responses than high-starch concentrates (barley, maize). The mechanism is probably associated with the faster degradation rate of starchy concentrates than of fibrous concentrates; which leads to a rapid increase in the ruminal lactate concentration and decreased pH, resulting in a reduced cellulolytic activity and therefore reduced rate of passage (Meijs 1986; Orskov 1994). Increasing the feeding frequency could help to alleviate the negative effects of starchy concentrates on the rumen environment (Orskov 1994).

The substitution effect of supplements is mainly manifested by a reduced grazing time (Leaver 1986). Supplementation studies reviewed by Krysl and Hess (1993) indicated that protein or starchy supplements to cows eating 6 to 15 kg herbage OM (6 to 8% CP) decreased daily grazing time by about 1.5 hours; whereas Sarker and Holmes (1974) found a mean decline in grazing time of 22 min/kg concentrate. It is expected that as pastures are grazed down, bite weight decreases and consequently, if daily herbage intake is to be maintained, grazing cows have to graze for longer periods and at increased rate of biting as swards conditions deteriorate towards a certain limit where the overall intake per day decreases (Burlisson *et al.* 1991; Manteca and Smith 1994). Rook *et al.* (1994a,b), have found that cows grazing on short swards (4 cm compressed sward height) decreased their grazing time when supplemented. The later suggested a threshold in energy intake below which cows are unwilling to continue grazing short swards (Rook *et al.* 1994a).

In summary, substitution rate will be greatest where pasture in offer is high (or extremely low) in quantity and quality, and where large amounts of starch-rich concentrates are fed (Kellaway and Porta 1993).

2.3.2.4 Effect of type and level of supplement

It has been established that the relationship between energy intake and milk yield is curvilinear (Gordon 1984). However, under stall feeding conditions the marginal milk production response to extra feeding (meals, silage or pasture) in late lactation is linear rather than curvilinear as occurs in early lactation (Stockdale and Trigg 1983; Stockdale and Trigg 1985; Stockdale *et al.* 1990; Grainger 1990; Stockdale 1995). This suggests that independent of substitution effects, at higher levels of extra feed in early lactation, the partitioning of energy towards milk synthesis decreases (Grainger 1990), probably associated with limited protein (Stockdale 1995); whereas in late lactation cows are limited by energy (Stockdale 1995). Grainger (1990) has suggested that much of the published variation in marginal response in early lactation can be explained by differences between experiments in feeding levels (Grainger 1990).

Two major effects of high quality spring pasture and also of intensively N-fertilized herbage are the reduction in milkfat concentration and the excessive loss of NH_3 (Mayne, 1991; Holden *et al.* 1994). Under these conditions, rumen microbes do not provide enough protein for high milk yields (Chalupa and Sniffen 1994; Stern *et al.* 1994). It has been reported that substitution rate of supplemental protein is lower than that of cereal grains (Rogers 1985) and animal proteins (e.g. blood meal) perform better than plant proteins (Stern *et al.* 1994). Then, theoretically high responses to rumen-undegraded protein may be expected if the availability of protein and carbohydrate in the rumen is synchronized (Holden *et al.* 1994). Nevertheless, this is still unproven under grazing conditions (Penno and Carruthers 1995).

Is likely that at low feeding levels, supplement type will have little effect on the milk production response (Rogers 1985). For example, when forage supplements are offered to grazing dairy cows at levels below 2.5 kg DM/day, little effect on milk yield or composition was observed (Mayne 1991); whereas, much greater effects on milk composition (increased milk fat content, but decreased protein

content) are observed when conserved forages form a larger component of the diet (>6 kg DM/day). On the other hand, when starchy concentrates are supplemented above 4 kg DM, the milk fat concentration is depressed, but the milk protein concentration is generally increased (Stockdale and Trigg 1985; Stockdale *et al.* 1987; Stockdale *et al.* 1990). The main reason for decrease in milk fat content is the reduction in the acetate to propionate ratio, which in turn reduces the use of protein for gluconeogenesis (Preston and Leng 1987). It has been estimated (Rogers 1985) that the rate of fat content decrease is about 2.2 g/kg supplemental oats; whereas, fibrous concentrates (e.g. beet pulp) maintain milkfat content (Mayne 1991; Van Vuuren *et al.* 1993). Beever (1993) has pointed out the great importance of legume components of pastures in buffering the decline in rumen pH.

2.3.2.5 Effect of genetic merit of cows (see also Section 2.2.4.3)

High genetic merit cows produce more milk, eat more feed, lose more body condition during the lactation and have a higher gross efficiency than their low genetic merit counterparts (Bryant 1981; Holmes *et al.* 1985). A greater partition of energy towards milk production has been suggested as the main reason for the superiority of high BI cows in gross efficiency (Kellaway and Porta 1993). Therefore, if cows of high BI partition more feed energy to milk production, there will be a greater marginal response to supplementary feeding. Grainger *et al.* (1985) and Holmes *et al.* (1985) found slightly higher but non-significant marginal responses by high BI cows to extra feed; whereas Robinson and Rogers (1982) and Stockdale *et al.* (1987) found that the initial milk yield of cow, had no influence on the marginal response, but high yielding cows (not necessarily high BI cows) lost more weight and partitioned more energy towards milk production.

2.3.2.6 Effect of quality of pasture and supplement

The interactive effect of pasture and supplement quality upon the milk production response has been comprehensively shown by the experiment conducted by

Stockdale *et al.* (1990) under stall pasture feeding (7 kg DM/day) of either good (70% IVDDM; 20% CP) or poor (62% IVDDM; 12.5% CP) quality pasture and supplemental crushed wheat (95% IVDDM; 10.4% CP) or high energy pellets (81% IVDDM; 16.6% CP). For good quality pasture, marginal milk responses were similar for both supplements; whereas the contrary was observed for poor quality pasture (Figure 2.8).

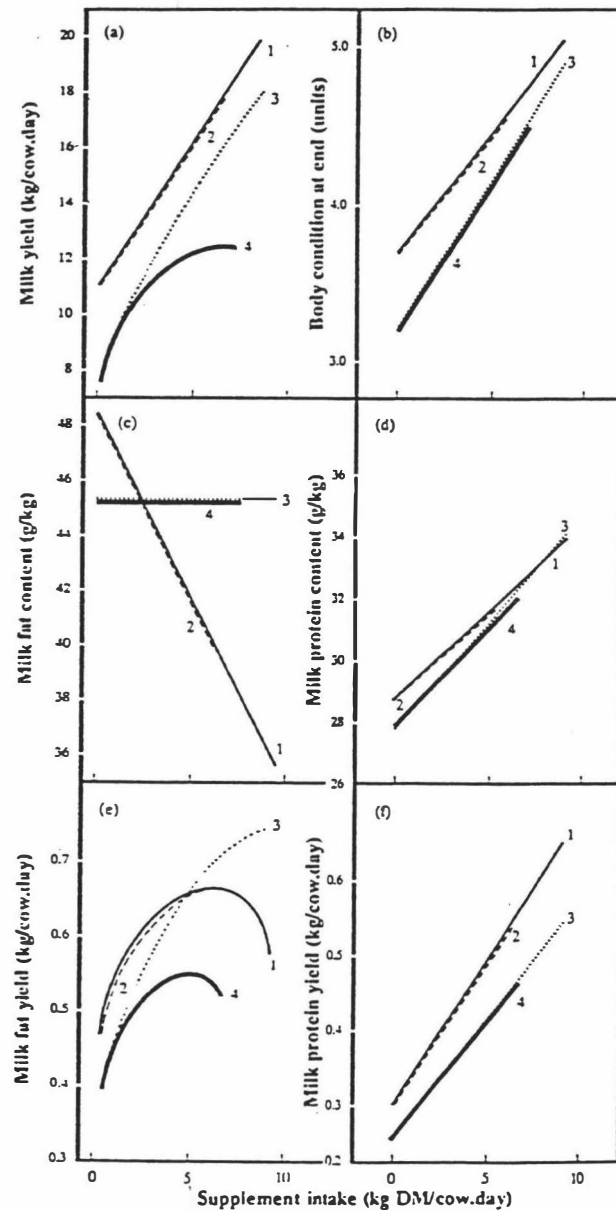


Figure 2.8: Effects of pasture and supplement quality on milk yield and composition (1, good quality pasture + pellets; 2, good quality pasture + wheat; 3, poor quality pasture + pellets; 4, poor quality pasture + wheat) (Stockdale *et al.* 1990)

Figure 2.8 (Stockdale *et al.* 1990) shows that with good quality pasture, milk fat yield responses were curvilinear and similar for both supplements; whereas with poor quality forages both supplements performed differently, the response being better for pellets than with crushed wheat. Milk fat concentration was maintained when both supplements were given under poor quality pasture; while under good quality pasture, increasing levels of both supplements reduced the milk fat concentration. It was concluded that fibre was the most limiting factor when good quality pasture was supplemented with concentrate; whereas protein was the most likely limiting nutrient when poor quality herbage formed the basal ration.

2.4 Increasing late lactation feed supply on seasonal dairy farms

In the New Zealand pastoral dairying system, the lack of feed over the second half of lactation is the main cause for the current average low daily milk yield and short lactations (Penno *et al.* 1995). It has been calculated (Penno *et al.* 1995) that a high performance per cow (Figure 2.9) can be achieved by reducing the rate of milk yield decline from the peak and achieving a long lactation. However, on seasonal producing dairy farms, pasture availability and condition score of cows are the main reasons for early drying-off dates (Parker *et al.* 1995).

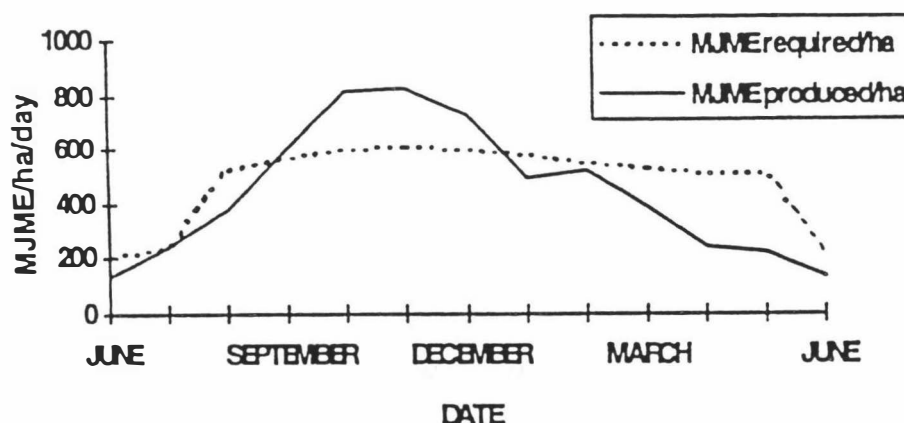


Figure 2.9: Seasonal energy (MJ ME/ha/day) relationship between the demand of a herd of "calculated cows" stocked at 3 cows/ha) and the pasture supply from No. 2 dairy (Ruakura) (Penno *et al.* 1995)

Extra days in milk at latter stages of lactation when pasture availability is low is normally associated with adverse effects on cow condition score (CS) and on farm average pasture cover, which in turn affect next season performance. For example, Bryant (1978) studied the effects of extending lactation by 5 weeks during March/April, comparing lactating and dried off cows, both at similar restricted feed intakes (i.e. similar change in pasture cover). At the end of the experiment the milking cows produced 17.8 kg MS/cow, but were 26 kg/cow lighter and 0.71 condition score/cow thinner than dry-off cows. Therefore, any extra feed input will be most effective in the second half of lactation and most importantly if extra days in milk is achieved.

2.4.1 Increasing feed production in late lactation

It has been indicated that milk solids yields close to the potential set by pasture production ("feed barrier") are being achieved on some New Zealand research and commercial farms (Hodgson 1989). However, scope exists in some of the rest of farms for increasing the feed supply by using fertilisation, irrigation, new species or cultivars or forage crops, drainage and control of pasture pests (Bryant 1983).

2.4.1.1 Fertiliser application

Nitrogen:

Pasture growth is responsive to N supply (Humphreys, 1991). However, the physical and financial outcome from the tactical application of N fertiliser on the dairy system is always uncertain (Roberts *et al.* 1990; Parker *et al.* 1994). Sources of risk associated with N fertilization decisions have been categorised as being production, price or financial (Martin 1994 cited by Parker *et al.* 1994). Production risks result from the biological processes of pasture growth and the efficiency of conversion of the grazed N-growth pasture; whereas price risks results from the N/MS price ratio (Hodgson 1989). In general, predictability of responses to early spring N applications is good, but autumn responses are much

less predictable (Tillman 1995). A recent expert scientist survey and interview - based research (Wright 1993 cited by Parker *et al.* 1994) have generated very useful information about pasture responses under alternative weather, application rate, grazing management and herbage mass conditions. For example, under warm weather the immediate response to 25 Kg N/ha applied to 1500 Kg/ha pasture cover might be 7.2 Kg DM/Kg N and the total response 12.3 Kg DM; whereas the maximum responses are likely to be obtained when herbage mass is around 2,200 Kg/ha.

The intensity of defoliation is the main factor which modulates the herbage production response to N fertilization. For example, under irrigated pastures Stockdale and King (1980) reported that the response to N fertiliser declined from 17 to 3 kg DM/kg N applied (four topdressings of 56 kg N/ha/year) as SR increased from 4.4 to 8.6 cows/ha. On the other hand, Penno *et al.* (1996a) obtained responses of 16.6 and 12.5 kg DM/kg N applied at levels of 210 and 381 kg N/ha/year, respectively; and the highest response was observed at the high stocked (4.48 cows/ha) and lower level N-fertilised farmlet; whereas the lowest response was observed when high-stocked farmlet received the higher level of N fertiliser.

Although pasture growth in response to N application increased, this was not reflected in milksolids production per cow (Stockdale and King, 1980; Penno *et al.* 1996a). In general, N fertiliser application at low SRs result in increased pasture accumulation but reduced herbage quality (King and Stockdale 1980). Thus, the only way to increase milk output per hectare from N fertiliser application appears to be by high SR.

Applying extra nitrogen fertiliser in the spring months to increase the amount of hay or silage harvested for summer and autumn have been suggested by Thomson *et al.* (1991) and Penno *et al.* (1995). In fact, silage harvesting increases up to 250% in response to N fertilisation (20-50 kg N/ha after grazing) have been reported by Penno *et al.* (1995), and Thomson *et al.* (1991) found an average

response of 132 g MS/kg DM conserved forage (hay and silage) fed in summer-autumn. The use of N fertiliser to create additional silage appears a profitable option to extend lactation length and reduce the concentrate input at high SRs (Penno *et al.* 1995).

Phosphorus:

Farm systems trials carried out in Taranaki have shown that dairying is responsive to continued P fertiliser applications even where the P status of the soil is high (>30 Olsen P) (Roberts and Thomson, 1991). For example, Thomson *et al.* (1993c) found responses of 2.5 to 5.5 and 1 to 1.5 kg MF/kg P, for low (18-29 Olsen P) and high (30-70 Olsen P) soil test, respectively. However, P application on soils high in Olsen P or higher levels of application (>50 kg P/ha) will be justified only under high utilization of herbage, i.e. high SR (Thomson *et al.*, 1993b).

Thomson and Holmes (1995) have pointed that pasture production and consequently milk production are more sensitive in later stages of the season (summer and autumn) to high P inputs.

2.4.1.2 Pasture species and forage crops for late lactation

Pasture species:

On pasture which is being produced at its maximum environmental potential (Scott *et al.* 1985), benefits in total production from introduction of new species are less than 10 % (Snaydon 1979 cited by Korte *et al.* 1987). However, there may be more scope for improvements in seasonal production and nutritive value (Hoglund and White, 1985) or where survival are more severely affected by pests and diseases (Hodgson, 1989).

In general, under similar digestibility in both fresh and conserved forms, white clover is superior to perennial ryegrass in its feeding value measured as milk yield, but milkfat concentration is reduced (Thomas, 1986; Stockdale 1992a; Wilkins *et al.* 1994). Recent experiments (1994-1995 season) at Taranaki Research Station (Johnson and Thomson 1996) evaluated feeding values of Kopu white clover, Yatsyn-1 perennial ryegrass, Kahu timothy and Kara cocksfoot offered at similar allowances of green leaf. Pasture species significantly affected both milk yield and milk composition. White clover increased MS production compared with all grass species. Timothy resulted in higher MS production than either ryegrass or cocksfoot. Timothy significantly increased fat %; cocksfoot depressed protein %; and white clover significantly increased lactose %.

Perennial ryegrass and white clover dairy pastures are associated with low persistence of low endophyte ryegrass. Endophyte-infected ryegrass varieties with high degree of resistance to Argentine stem weevil have been developed, but the toxins produced (Lolitrems) have been associated with reduced palatability and also reduction of animal performance and ryegrass staggers (Hunt 1987; Clark 1995). For example, low endophyte (20-30% infection) pastures produced 10 to 39 % more milksolids than high endophyte (>80% infection) pastures in summer (Thom *et al.* 1994). The recently successful introduction of the Argentine stem weevil parasitoid may allow increased persistence of low endophyte ryegrass (Clark 1995).

Tall fescue, Phalaris, Matua Prairie grass, Cocksfoot and Limpograss have been reported to be more productive than the conventional ryegrass-white clover pastures over the summer-autumn period on drought-prone areas (Cosgrove, 1987; McCallum *et al.* 1992; Clark 1995). However, because of their lower feeding value, benefits of these species on milk production have not been proven (Thomson and Holmes 1995). It has been suggested that a particular species or combination of species must be fit in the most appropriate environment and management conditions in order to reach the maximum potential of production (Scott 1993).

Turnips:

Turnip cropping for summer feeding has become a common practice on dairy farms. A recent survey (Clark *et al.* 1996) revealed that on average 4.3% of the farm is sowed in turnips, mainly Barkant cultivar with yields ranging from 0 to 15 t DM/ha (average 7.4 t). Rainfall in November and December but not January was positively associated with turnip yield. Simulation (UDDER model) of gross margin derived from turnips cropping (Clark 1995), which took account of the losses in pasture production due to cropping, showed that in normal year the break-even point for turnips is about 10 t DM/ha yield; whereas in dry or drought years it is 8 t DM/ha yield. Supplementing pasture with 5 kg turnip DM/cow/day at Taranaki (Clark *et al.* 1996) gave immediate marginal milk responses of 36 g MS/kg turnip DM. In the first experiment control cows ate 10 kg pasture DM; whereas in the second, pasture allowance was 10 kg DM/cow/day (measured above 4 cm). At the end of the experimental period (18 days) supplemented cows were 6 kg lighter, but 0.3 CS higher than non-supplemented cows. Cows lost liveweight and condition score in both period.

Feeding trials conducted at Ruakura (Penno *et al.* 1996b) in the summer and autumn of 1995 (48 days) showed that under restricted pasture allowances, cows supplemented at levels of 4 and 8 kg turnip DM/cow produced 50 and 26 g MS/kg turnip DM response, respectively; whereas, condition score was maintained by the supplemented and non-supplemented cows. A subsequent experiment showed that groups of cows grazing 8 Kg DM/cow/day and given extra 10 kg DM of pasture or combinations of pasture and pasture silage did not differ in MS production or body condition score.

Greenfeed maize:

Maize is a high DM yielding forage crop, which may fill the feed shortage during the late season as silage or greenfeed (Kirley 1977; Ridler 1982). Its high energy value and its high intake rates are valuable attributes for lactating cows feeding

(Phipps 1988). An experiment carried out at Ruakura (Campbell 1982) revealed that cropping costs of maize made its inclusion in dairying unprofitable. Computer simulations (Clark 1995) have indicated that greenfeed maize is likely to have greater advantages than turnip cropping on drought growing situations. Thus, DM yields are the major determining of profitability of any forage crops (Phipps 1994).

2.4.1.3 Irrigation for late lactation

Deficit in soil moisture is the main factor restricting pasture growth in the second half of lactation (Thomson and Holmes 1995). Irrigation during summer season will usually result in a considerable increase in pasture growth, but the magnitude of the response will depend on magnitude of moisture deficit (Holmes and MacMillan 1982).

Large increases in milk production and changes in the pattern of milk supply can be achieved by irrigation (Andrewes 1995). For example on a Northland farm, production was increased from 794 to 1219 kg MS/ha when a 100% of the milking area was irrigated, and milk supply in the second half of the lactation was increased considerably with longer lactations. The extra pasture production due to irrigation was between 3 to 5 t DM/ha, although there was some reduction in winter pasture growth.

Costs of irrigation infrastructure are high (e.g. \$2700 to \$5000/ha in Northland) and there are also extra running costs, consequently costs per unit extra milk produced are high. For example, farmlet studies involving low BI cows carried out by Hutton (1978) showed that even though milkfat production was increased by 100-170 kg/ha, irrigation was uneconomic. Management must take full advantage of irrigation's benefits if long-term profit is expected.

2.4.2 Use of supplementary feeds in late lactation (see also Section 2.3)

Studies about use of supplements on seasonal dairying system have mostly concentrated on early lactation and use of supplements in late lactation has been suggested to be ineffective because of the greater partitioning of nutrients towards body gain (Stockdale *et al.* 1987; Stockdale and Trigg 1989; Kellaway and Porta 1993). However, under the current costs and prices concentrate supplementation in New Zealand seasonal dairying is unprofitable even at high stocking rates (McCallum *et al.* 1995).

Recent research findings (Clark 1993; Holmes *et al.* 1994; McCallum *et al.* 1995; Penno *et al.* 1995, 1996a; Stakelum *et al.* 1995) have shown that supplementary feeding in latter stages of the lactation gave greater milk responses than that conventionally quoted, especially if extra days in milk is gained with supplementary feeding.

2.4.2.1 Concentrates

Results from concentrate feeding trials carried out at the No. 2 Dairy (Ruakura) and Waimate West Demonstration Farm (WWDF, Taranaki), have been summarised by Penno *et al.* (1995). Milk production response to early lactation, early summer and late summer-autumn concentrate feeding were 13, 60 and 115; and 94, 81 and 177 g MS/kg DM, respectively for Ruakura and WWDF trials, respectively. They concluded that in a pasture based seasonal dairy farming, the effect of supplementary feeding on achievable days in milk, during periods of low availability of pasture in mid and late lactation, is more important than the stage of lactation effects on the partitioning of extra feed energy to milk production. The large increases in milk yields after the end of January were directly related to extra days in milk (Penno *et al.* 1996a). Thus, unless cows are been severely underfed in early lactation, supplements at this time would not be recommended, but supplementary feeding to overcome the summer/autumn feed deficit would be recommended at reasonable supplement prices (Thomson and Holmes 1995).

2.4.2.2 Maize silage

Maize is a high yielding (20-25 t DM/ha) crop (Clark 1995), for which utilization can be maximised by silage making. Silage fermentation, voluntary intake and animal production are improved by chopping (Stockdale and Beavis 1994).

Maize silage supplementing to grazing dairy cows (Reardon *et al.* 1976) suggested that if maize silage forms more of the 75% of the ration, milk yield will be reduced by deficiencies in N, Ca, Mg, P, Na and S. Recently, series of stall feeding experiments conducted by Stockdale (1995) found that marginal response of silage feeding at up to 5 kg DM/cow/day to cows eating about 7 kg DM/day of pasture was 0.89 kg extra milk/Kg silage DM in early lactation and 0.63 in late lactation. High levels of maize silage feeding (>40% of the ration) in early lactation were detrimental to milk production; while in late lactation, milk production response was linear when maize silage was fed up to 12 kg DM/cow/day. Another experiment (Stockdale 1992b) included maize silage, barley or cottonseed meal supplementation (5 Kg DM/cow/day) to grazing cows in late lactation and found similar milk response between supplements. These results suggested that protein is a limiting nutrient in early lactation, but not in late lactation.

2.4.2.3 Pasture silage

It is generally considered that the process of ensiling leads to a reduction in voluntary intake and milk production. Cushnahan and Mayne (1995) have found no significant difference in milk yield and composition between cows offered pasture or restricted fermented silage made from the same sward as a sole food, but extensively fermented silage produced reduced milkfat and milk protein responses.

Wilting and chopping the herbage prior to ensilage in order to improve fermentation quality and therefore animal performance are widely recommended.

However it have been suggested that under systems where silage is used as a late lactation supplement, neither wilting (Carruthers 1985) nor fine chopping (Moate *et al.* 1985) are justified in terms of extra milk production.

A silage workshop recently convened in Hamilton (Howse *et al.* 1996) agreed quality targets (Table 2.1) for pasture silage to be fed to lactating dairy cows. When these targets are compared to the national silage average (samples analyzed through the Lincoln University Laboratory) (Table 2.1), a good conservation process was apparent ($\text{NH}_3\text{-N}\%$ below 10% and pH 4.5-5.0). However the average feed quality as assessed by CP (15%), DMD (67-68%) and M/D (9.3-9.5) was poor. Delay in cutting date and time interval between shutting date and cutting date were identified as the two main reasons affecting silage quality in New Zealand (Burnham *et al.* 1995; Mudford 1995; Howse *et al.* 1996) and Australia (Rogers 1985). These two factors act through the stage of growth, which has been identified by various authors reviewed by Harrison *et al.* (1994) as the more important determinant of silage quality than other management factors.

Table 2.1 Comparisons between target values for high quality pasture silage and quality indicators for current practice New Zealand silages (from Howse *et al.* 1996).

Indicators	Targets for high quality silage ¹	Lincoln University Laboratory ²	
		Bale	Pit or Stack
DM% (bale)	30-35	45	
DM% (pit or stack)	25-30		31
pH	3.5-4.5	5.1	4.5
$\text{NH}_3\text{-N}$ (% N)	< 10	7.1	9.4
CP (%)	16-20	14.6	15.0
DMD (%)	> 70	66.6	68.0
M/D (MJ ME/kg DM)	> 10	9.3	9.5

¹ Agreed targets at the Hamilton silage workshop, Hamilton, 1994.

² Means for 150 and 440 samples of bale and pit or stack silage, respectively analyzed over the period June 1994-May 1995.

From early and late season silage supplementation to continuous grazing dairy cows, Phillips and Leaver (1985b) indicated that in early season milk yield was decreased by offering silage; whereas in late season, milk yield and liveweight were improved. For example, milk response to 4 kg silage feeding in late season was 14 g MS/kg silage DM. Milkfat concentration was increased in both periods by silage feeding, and the higher milkfat yield in the early season counterbalanced the reduction in protein yield in this period. Herbage substitution operated mainly through reduction in grazing time. In fact, grazing time decreased as the level of supplement increased; whereas biting rate was maintained. Bite size decreased as the amount of supplement increased; whereas ruminating time increased in direct relation to supplement level. A reduction in grazing time of 43 min/day for the consumption of 1 kg of silage DM was reported (Mayne, 1991).

From a review of 11 experiments in which wilted silages was fed, Rogers (1985) found an average response of 36 g MF/kg silage DM. On the other hand, Moate *et al.* (1984) reported that at 7.5 kg DM/cow/day pasture allowance, a response of 16 g MS/kg silage DM was obtained when silage was supplemented at 6 kg DM/cow/day; whereas at the higher level of pasture allowance (15 kg DM/cow/day), only a lower level of silage feeding (3 kg DM/cow/day) produced significant responses (34 g MS/kg silage DM). Substitution occurred even at the lower level of pasture allowance. A recent experiment carried out at Moorepark, Ireland by Stakelum *et al.* (1995) showed no benefit of silage feeding to autumn pasture grazing dairy cows at good supply of pasture.

Bryant and MacDonald (1987) evaluated effects of feeding 4 kg pasture silage DM to grazing cows in summer (during 4 weeks). They found an immediate marginal response of 46 g MS/kg silage DM. By the end of the experiment supplemented cows had lost less condition score (-0.7 vs -0.8) and their farmlets had higher pasture cover (2000 vs 1860 kg DM/ha) than un-supplemented cows.

Few studies have evaluated the effects of supplements on the whole dairy system. Clark (1993) conducted farmlet trials to evaluate the effects of feeding 5 kg

DM/cow silage (M/D, 10.8 MJ ME/kg DM; CP, 13.3%) either in early, mid or late lactation at 3.8 cows/ha stocking rate. Late lactation supplemented cows produced extra 0.33 kg MS/cow/day and at the end of experiment they were 2 kg/cow heavier but 0.3 condition score/cow thinner than non supplemented cows. The average farm cover was reduced by 230 kg DM/ha in both supplemented and non-supplemented farmlets. The immediate marginal response in late lactation was 66 g MS/kg DM silage when the extra days in milk (7 of total 36 days experimental period) was included and 50 g MS/kg DM silage after corrected by extra days in milk. This level of response was greater than in spring or summer silage feeding (26 and 16 g MS/kg silage DM, respectively). When carryover effects of early and mid lactation silage feeding were considered, the total milk responses were similar (39 g MS/kg silage DM) for both periods. Carryover effects of autumn silage feeding were not estimated.

Similarly, another farmlet experiment carried out in late lactation (April-May) at Massey University (Holmes *et al.* 1994) using 8 kg DM/cow/day of a 50:50 mixture of grass silage and apple pomace to milking cows eating 7 kg pasture DM/cow/day compared to dried-off cows eating the same amount of pasture, found that during the 32 day period of extended lactation, cows produced 40 kg MS and they did not lose body condition, but dried off cows gained 0.7 condition score. In addition the dried-off farmlet had an extra 180 kg DM/ha pasture cover by the end of the experiment. When the probable carryover effects of the lower CS of the milked cows and the lower pasture cover of their farmlet were accounted, a theoretical total marginal milk production response of 92 g MS/kg DM was calculated.

2.4.2.4 Hay

Sangsritavong and Holmes (1991) found that hay of moderate digestibility (57% DMD) fed to appetite to grazing dairy cows in early lactation at 12 kg DM/cow pasture allowance, resulted in slightly more milk yield (1.3 l/day) and also higher liveweight gain than in cows supplemented with low digestibility hay (52%

DMD). The marginal response of cows in the moderate DMD was 0.5 kg milk and 0.15 kg liveweight/kg extra hay DM, but they substituted 0.2 kg pasture DM per kg extra hay DM eaten. Whereas, Rogers (1985) stated that even at very severe levels of pasture restriction (4 kg DM daily intake), low quality hay fed *ad libitum* achieved only 80% milk yield of that from pasture.

Phillips and Leaver (1985a) reported increased milk yield (0.89 kg milk/kg hay DM) from hay feeding (1.5 to 1.8 kg DM/cow/day) to continuously stocked cows at high SR (4.9 cows/ha) in early lactation; these benefits were greatest for the higher yielding cows. However, hay supplementation in late lactation promoted mainly liveweight gain. Grazing behaviour was affected in the same ways as by silage feeding (Phillips and Leaver 1985b) (see Section 2.4.2.3).

Hay supplementation was unable to completely overcome the effects of reduced pasture intake (7 kg pasture DMI) in early lactation (Stockdale *et al.* 1981); whereas in late lactation the effects of reduced pasture intake were overcome by hay feeding (King and Stockdale (1981). In fact, in late lactation, total DM intake was the most important determinant of animal performance.

2.4.2.5 Industrial by-products

A range of industrial by-products (vegetable peelings, fruit pulp, low grade fruit, whey, brewers' grain) can be utilised in supplementing grazing dairy cows (Edwards and Parker 1994). For example, apple pomace has a relatively high energy value (11.6 MJ ME/kg DM), and a 50:50 mixture of grass silage and fresh apple pomace has been successfully utilised by Holmes *et al.* (1994) to extend lactation. A subsequent late lactation supplementary study (Edwards and Parker 1995) found that at the same herbage intake (6 kg/day), cows supplemented with 3 kg DM/cow/day pasture silage plus 4 kg DM/cow/day apple pomace produced 22% more MS (1.236 vs 1.013 kg MS/cow/day) than cows supplemented with 7 kg DM pasture silage, with no differences in condition score.

2.5 Summary of this Chapter

The tight financial constraints under which New Zealand dairy farmers operate determines that feeding must be almost entirely based on grazed pastures, which is achieved by matching the herd's feed requirements to the seasonal feed supply. On these conditions farm profitability is closely related to output per hectare, where overall productivity is determined by pasture production, the efficiency of pasture harvesting and the efficiency of feed conversion into milk.

Decisions about calving and drying off dates are important to match feed demand to the seasonal pasture production, but most importantly stocking rate has the dominant effect in determining grazing efficiency and profitability per hectare. Genetic merit of cows is the main determinant of feed conversion efficiency, but its potential effect on milk yield per cow is limited by the low feeding levels caused by high stocking rates. Grazing management is of minor importance, except in its effects on the management of seasonal feed surpluses or deficits.

Furthermore, calving and drying-off dates, through their effects on days in milk, are important determinants of production per cow. Calving date affects directly the level of production of the herd, especially in early lactation. In turn, drying-off date determines the lactation length and also influences the status of body condition and pasture cover at dry-off and subsequently at calving. Replacement during the dry period (winter, when pasture growth rates are low) of condition lost during lactation is expensive in terms of feed, therefore cow condition is an important determinant of drying off date, as is the on-farm pasture cover.

The average days in milk of New Zealand herds (208 days in 1994-95) is extremely low compared to the standardised 305 days of high input systems. Maintenance requirements of cows, irrespective of whether they are dry or lactating is a fixed cost of feeding; because of that, late lactation offers good scope for extra milk production with a good marginal response from extended days in milk if extra feed is given at this stage.

Extending the length of lactation normally results in higher milk production, but it can be at the expense of the next seasons performance because both condition score and average pasture cover can be lower than the minimum targets required at calving. In practice, extra days in milk may be gained if relatively cheap extra feed is given to cows at the end of lactation. However careful planning must be made in order to avoid severe lost in cow condition and average pasture cover. Continuing milking only the highest yielding cows, which are above a minimum condition score (4.5) appears be the best alternative.

The relative benefits of the available feed inputs and their effects on milk production responses in the short and long terms, must be evaluated before the formulation of conclusions.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location and duration of the experiment

The experiment was carried out at the Dairy Cattle Research Unit (DCRU), Massey University, Palmerston North, from 4th April to 29th May 1995. The experiment involved a total of 118 cows, predominantly Holstein-Friesian, on 40 hectares of ryegrass-white clover pastures.

Rainfall in April and May 1995 were 115 and 80 mm, respectively, while the corresponding soil temperatures (10 cm) were 15.5 and 11.5 °C, respectively (Anonymous 1995). Pasture growth rates in April and May 1995 were 43 and 30 kg DM/ha/day, respectively (Anonymous 1995); these rates being 87% higher for April and 12% lower for May, compared to those of the 10-year averages (Anonymous 1995).

3.2 Animals and treatments

Two treatments were applied, and each was duplicated. The two treatments were two systems of management in late lactation:

1. Dried-off (D) and grazed on pasture.
2. Milked for extra days (M), grazed on pasture and given supplementary feed.

Fifty-four cows were dried-off (D) on 4th April (average of 219th days in milk) because they were thinner, low yielding or younger, while the remaining 64 cows continued to be milked (M) until 29th May. The 54 D cows were divided into two equal herds, balanced for age, live weight, previous milk yield and condition score, and each herd was grazed on a self-contained farmlet of 9.2 ha. Similarly, the 64 M cows were divided into two herds and each herd grazed on a self-

contained farmlet of 10.8 ha. The average conditions at the start of the experiment are shown in Table 3.1.

Table 3.1: Mean (for two dried-off and two milked farmlets) animal and pasture conditions at the start of the experiment (4th April) (mean±s.e.¹)

Parameters	Dried-off (D)	Milked (M)	sig ^{1,2}
Area of farmlet (ha)	9.2	10.8	
Number of paddocks	11	12	
Number of cows	27	32	
Stocking rate (cows/ha)	2.9	2.9	
Age of cows (years)	4.9±0.3	6.3±0.3	**
Live weight (kg/cow)	452±6.0	484±5.5	***
Condition score (scale 1 to 10)	4.43±0.07	4.29±0.07	ns
Daily milk yield (kg MS/cow)	0	1.14±0.03	
Average pasture cover (kg DM/ha)	2231±18	2228±18	ns

¹ Where appropriate.

² Significance of difference: ^{ns}P>0.05; ^{**}P<0.01; ^{***}P<0.001.

3.3 Grazing and feeding management

Each of the 4 herds and farmlets were managed and grazed as 4 separate farms. All herds grazed a fresh break of pasture each day. The D herds ate only grazed pasture at restricted levels, while M herds grazed pasture at generous allowances and were also supplemented with pasture silage of relatively poor quality (see Table 3.2), which was fed on the paddock once a day after morning or evening milking (depending on weather) at between 0 to 12 kg DM/cow/day (depending on the amount of pasture offered at the time).

All farmlets were operated to a feed budget which had common targets for 29th May of 2000 kg DM/ha pasture cover and condition score 5. Thus, the area of the daily breaks of pasture allowed to the herds were estimated in order to supply

energy requirements (above maintenance and pregnancy requirements) for 1 kg LW gain/day by both D and M cows, plus 1.2 kg MS/day by M cows, and for residual herbage masses of 1100 and 1600 kg DM/ha for D and M farmlets, respectively. Silage was offered to the M herds as a buffer against reduction in body condition and in average pasture cover, and to meet their higher energy requirements.

Table 3.2: Dry matter (DM), metabolisable energy (M/D) and crude protein (CP) contents of the pasture silage supplement (average±s.d.)

DM (%)	34±1.2
M/D (MJ ME/kg DM)	9.0±0.3
CP (% DM)	13.2±0.9

3.4 Measurements

3.4.1 Pre- and post-grazing herbage mass

Pre-grazing herbage mass (PGHM, kg DM/ha) and post-grazing or residual herbage mass (RHM, kg DM/ha) were determined daily for each break on each of the four farmlets. A rising plate meter (Ashgrove, N.Z., LTD) was used to estimate herbage mass (HM, kg DM/ha) (Holmes 1974; Earle and McGowan 1979). The average value of 30 rising plate meter readings (PMR) was related to HM by the standard equation used at the DCRU:

$$\text{HM (kg DM/ha)} = 200 + 158 \cdot \text{PMR}$$

3.4.2 Herbage allowance

The daily herbage dry matter allowance (HDMA, kg DM/cow) was calculated as the pre-grazing herbage mass multiplied by the area of the break and divided by the number of cows in the herd.

3.4.3 Stocking density

The daily stocking density (SD, number of cows/ha) was calculated by dividing the size of the herd (number of cows in the herd) by the area of the daily break grazed for the herd.

3.4.4 Apparent daily herbage intake

The daily herbage intake was estimated as the herbage dry matter disappearance (HDMD; i.e. the difference between the pre- and post-grazing herbage mass) multiplied by the area of the daily break offered and divided by the number of cows in the herd. Consequently, the daily herbage intake estimated in this way is the apparent herbage dry matter intake (AHDMI).

3.4.5 Botanical composition and nutritive value of the grazed herbage and silage

Herbage samples were taken fortnightly from cage-protected areas for analysis of botanical composition and nutritive value. Four cages (0.25m x 1.00m) were placed on the pasture break prior to grazing and once the cows had been removed to another area, the herbage in each cage was plucked to imitate the grazed horizon of the surrounding area. The total herbage collected was pooled and subsamples were taken for botanical composition and nutritive value analysis.

Botanical composition was analyzed for species composition and also for live and dead (including senescent) material. Once the herbage was separated into botanical components, these were washed, oven-dried (90 °C for 18 h) and weighed.

The nutritive value of herbage was analyzed on washed and freeze-dried samples. *In vitro* digestibility was determined using an enzymic method (Roughan and Holland 1977), whilst total nitrogen (N) was determined by the Kjeldhal procedure. Metabolisable energy content (M/D value, MJ ME/kg DM) of the

grazed herbage was estimated by multiplying the digestibility of the organic matter (DOMD) by the factor 0.16 (CSIRO 1990).

Silage samples were taken fortnightly from the paddock, then freeze-dried and analyzed for DOMD digestibility and N content using the methods described above. Both herbage and silage samples were analyzed at the Nutrition Laboratory, Massey University.

3.4.6 Live weight (LW) and condition score (CS)

The cows were weighed and condition scored after the morning milking on two consecutive days at the beginning, in the middle and at the end of the experiment. Body condition score was assessed visually on a scale 1 to 10 (1, very thin; 10, very fat) according to the recommendations outlined by Holmes *et al.* (1987).

3.4.7 Feeding behaviour

Feeding behaviour was monitored towards the end of the experiment (day 42nd and 49th) day when the grazing conditions were markedly different between the treatments. On day 42nd M herds were silage supplemented; whereas in the day 49th they were not supplemented.

Feeding behaviour was assessed by direct observation for 24 hours (a torch was used for night observation) using the interval sampling technique (Hodgson 1982). For this purpose the working day of the grazing cow was divided into alternating periods of grazing, silage eating, ruminating and doing other activities (resting, drinking, milking and walking). Cows in each of the four herds were watched at intervals of 15 min and the number of cows engaged in the major activities was categorised (Hodgson 1982). Thus, the total time spent by the average cow on each major activity and its temporal distribution were estimated from the proportion of the total number of observations (visual scans) over the 24-hour observation period (Bao *et al.* 1992).

The rate of biting was measured using the 20-bite technique (Hodgson 1982). The biting activity was identified as the severance of a bunch of herbage and the time for which an animal is actively seeking acceptable mouthfuls of herbage to bite (Hodgson 1982). Rate of biting was measured at different times during the day (07.30, 09.00, 12.00 and 16.00 hours). At each time, 20 cows were chosen at random and closely observed, and the time required for each animal to take 20 bites was recorded. Biting rate was expressed in terms of number of bites per minute.

3.4.8 Milk yield and composition

Individual milk yields (l) were recorded at each milking (evening and morning), whereas milk composition (Milkoscan, Denmark) for each cow was analyzed from samples collected over two consecutive days (48 hours) per week. Daily milk solids (MS, fat plus protein) yield for each cow (kg MS/cow/day) was estimated from the milk composition multiplied by the daily milk yield for each cow.

3.4.9 Average pasture cover

The average pasture cover (APC, kg DM/ha) for each farmlet were estimated at the start, and on days 7, 21, 35, and at the end of the experiment. The rising plate meter was used to estimate the herbage mass on each paddock. Then the APC was calculated as the weighted (by the size of the paddocks) average herbage mass for each farmlet.

3.5 Statistical analyses

The two systems of management (Dried off (D) or Milked plus supplement (M)) were considered as treatments (with 2 farmlets each). Analysis of variance showed that there were no significant differences ($P > 0.05$) when the effects of farmlets were included in the model. Therefore, differences between the treatments were analyzed on the pooled data using the generalized linear model of SAS (SAS

1985). Live weight gain (LW Δ) and condition score gain (CS Δ) were compared after covariate (initial records of each variable) effects adjustment.

Daily apparent herbage dry matter intake per cow (AHDMI), pre-grazing herbage mass (PGHM), residual herbage mass (RHM), herbage allowance (HDMA) and stocking density (SD) were analyzed for weekly average records (n=14) obtained for each herd; whereas, the average pasture cover (APC), nutritive value and botanical composition of the herbage and the grazing behaviour were compared on whole farmlet basis (n=2). Data for live weight, condition score and milk yield of the individual cows were analyzed for each period of measurement (n=54 and 64, for D and M cows, respectively).

CHAPTER FOUR

RESULTS

4.1 Grazing conditions and level of feeding

Mean values for daily feeding management are given in Table 4.1. Grazing conditions differed significantly ($P < 0.001$) between the treatments. As was planned, the milked (M) cows grazed a larger area each day, with a lower daily stocking density, and a larger daily herbage allowance (HDMA). The pre-grazing herbage mass (PGHM) was higher on the D farmlets than on the M farmlets, and D paddocks were grazed to lower residual herbage masses (RHM) than the M paddocks.

Table 4.1: Mean values for daily feeding management and apparent intakes during the 54 days of the experiment (mean \pm s.e.)

Parameters	Dried-off (D)	Milked (M)	sig ¹
<u>Daily feeding management:</u>			
Area grazed (m ² /cow)	48 \pm 1.5	109 \pm 1.5	***
Stocking density (cows/ha)	212 \pm 6.3	95 \pm 6.3	***
Herbage allowance (HDMA, kg DM/cow)	16.3 \pm 1.4	29.9 \pm 1.4	***
Pre-grazing mass (PGHM, kg DM/ha)	3449 \pm 105	2734 \pm 105	***
Residual mass (RHM, kg DM/ha)	1042 \pm 29	1421 \pm 29	***
<u>Daily apparent intakes:</u>			
Pasture (AHDMI, kg DM/cow) ²	11.6 \pm 0.7	14.2 \pm 0.7	*
Silage (kg DM/cow) ³	0	5.5 \pm 0.7	***
Total (TADMI, kg DM/cow)	11.6 \pm 0.3	19.7 \pm 0.3	***
Total (TAMEI, MJ ME/cow) ⁴	115 \pm 3.8	206 \pm 3.8	***

¹ Significance of difference: * $P < 0.05$; *** $P < 0.001$.

² Estimated from before- and after-grazing difference in herbage mass.

³ Estimated as total silage (DM) fed divided by the number of cows in the herd.

⁴ Total DM apparently eaten multiplied by the average M/D (MJ ME/kg DM) values:
D Pasture=10; M Pasture=1 l; silage=9.

The apparent pasture intake (AHDMI) was higher for the M cows ($P < 0.05$) than for the D cows (14.2 and 11.6 kg DM/cow/day, respectively) (Table 4.1). On average 5.5 kg silage DM were fed daily to M cows and the refusal probably accounted for 10 to 15% of the total silage fed. Total apparent daily intake of DM (TADMI) and metabolisable energy (TAMEI) were significantly higher ($P < 0.001$) for M cows (19.7 kg DM and 206 MJ ME) than those of D cows (11.6 kg DM and 115 MJ ME).

Figure 4.1 illustrates the mean daily apparent pasture intake (AHDMI) and the total apparent dry matter intake (TADMI; i.e. pasture plus silage for M cows) by D and M cows for each week of the experimental period. The AHDMI of D cows increased slightly from the start to the 4th week (from 9.2 to 12.6 kg DM/cow/day) of the experiment; maintaining the later level to the end of the experiment. On the other hand, the AHDMI of M cows had a big increase from the start to the 3rd week (from 13 to 20.5 kg DM/cow/day) of the experiment; after that it decreased gradually to the 6th week of the experiment (10.3 kg DM/cow/day); and this level was maintained to the end of the experiment. The TADMI ranged from 9.2 to 13.1 and from 18.2 to 23.4 kg DM/cow/day, for D and M cows, respectively. Silage was not fed during the second and third week of the experiment.

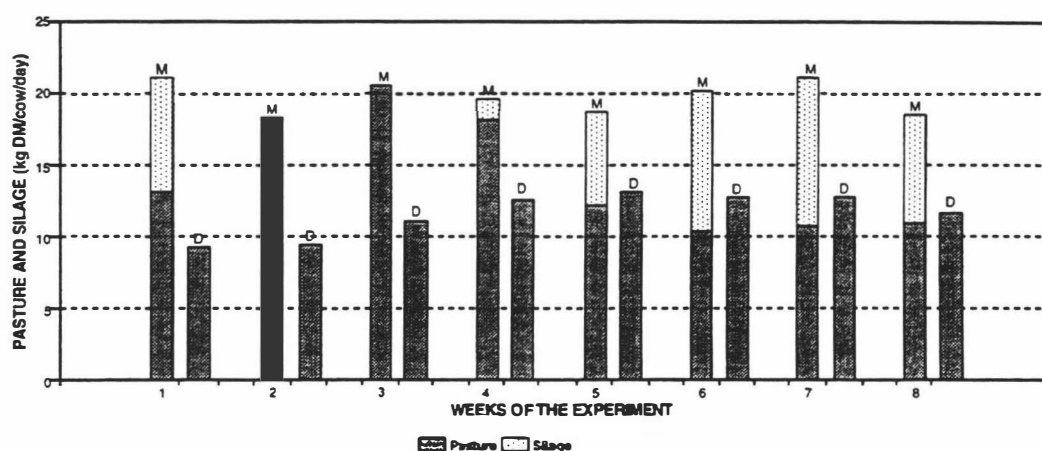


Figure 4.1: Total apparent dry matter intake (TADMI, kg DM/cow/day) (pasture and silage) for dried-off (D) and milked (M) cows throughout the experimental period

Relationships between the daily herbage allowances (HDMAs) and the apparent herbage intakes (AHDMI) throughout the experimental period are illustrated by Figures 4.2a and 4.2b, respectively for D and M cows. The daily AHDMI of both D and M cows were positively related to their HDMAs, but a closer relationship between these parameters was observed for the D cows (Figure 4.2a) than for the M cows (Figure 4.2b) (see also Equations 4.1 and 4.2, Table 4.8).

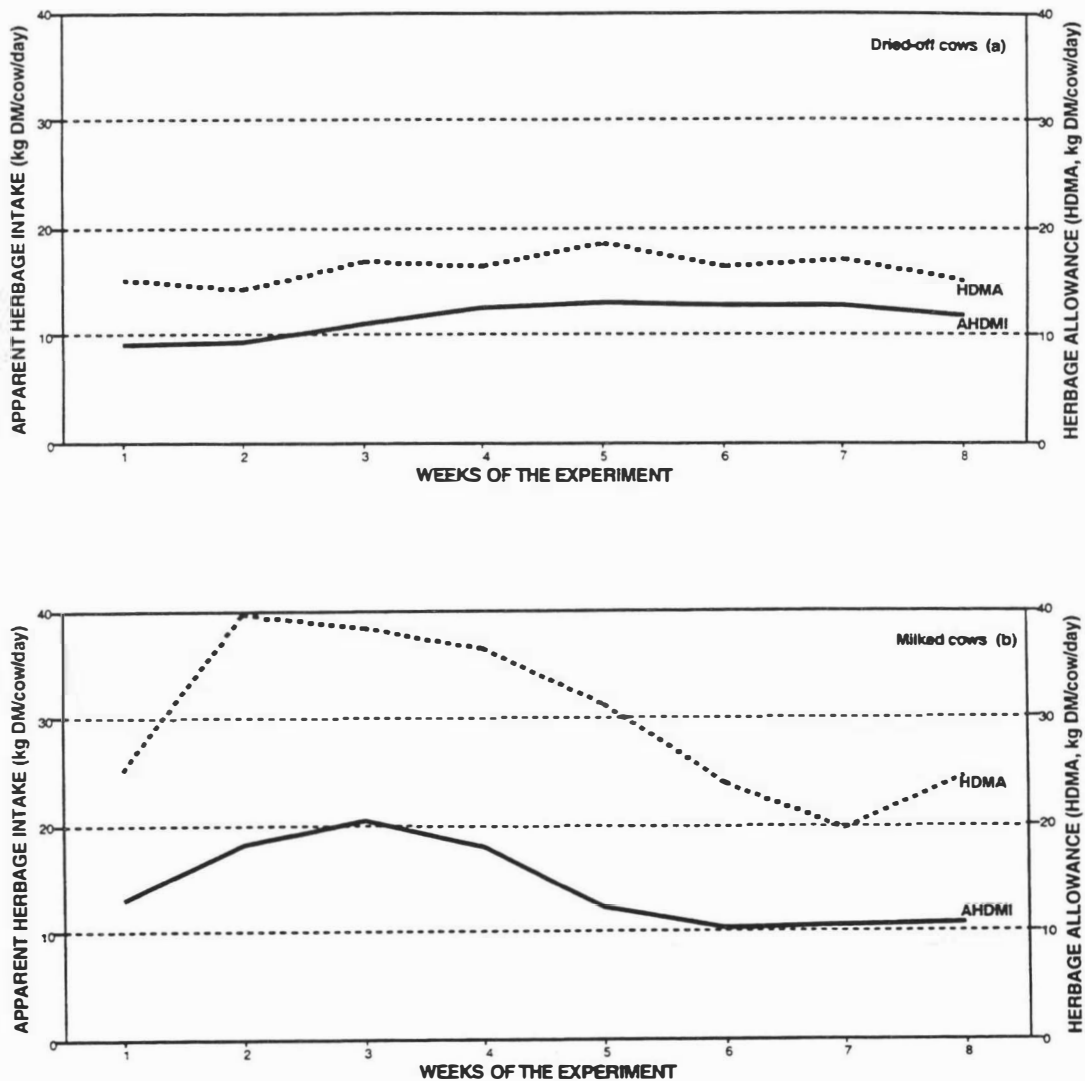


Figure 4.2: Weekly mean values for herbage allowance (HDMA, kg DM/cow/day) and apparent herbage intake (AHDMI, kg DM/cow/day) for dried-off (D) (a) and milked (M) (b) cows throughout the experimental period

Figures 4.3a and 4.3b, show the relationships between the daily PGHMs and RHMs, and the daily AHDMI for the D and M cows, respectively. The daily AHDMI of both D and M cows were positively related to their PGHMs and RHMs. These relationships were closer for the M cows (Figure 4.3b) than for the D cows (Figure 4.3a). The daily PGHMs for D cows increased throughout the experimental period (Figure 4.3a); while the contrary was observed for the M cows (Figure 4.3b). The daily RHMs for both D and M cows were maintained within a small range of variation throughout the experimental period. The above described relationships are also supported by the regression analyses of AHDMI of D and M cows on their respective PGHMs and RHMs (Table 4.8, Section 4.7).

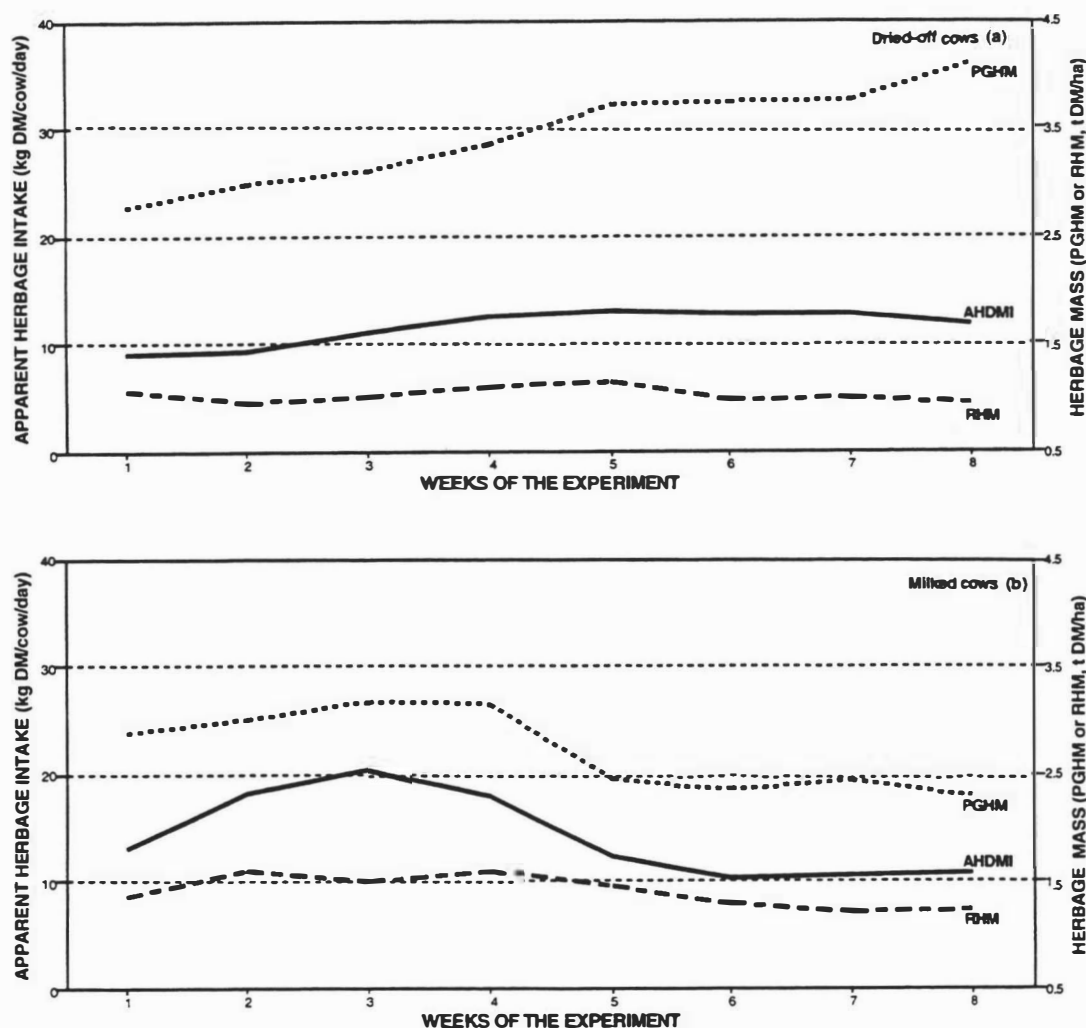


Figure 4.3: Weekly mean values for the pre-grazing and residual herbage masses (PGHM and RHM, t DM/ha) and the apparent herbage intake (AHDMI, kg DM/cow/day) for dried-off (D) (a) and milked (M) (b) cows throughout the experimental period

4.2 Botanical composition and nutritive value of the grazed herbage and silage

The main features of the botanical composition and nutritive value of the grazed herbage are shown in Table 4.2. D cows grazed herbage of higher DM content than M cows ($P<0.001$), but the live and dead material proportions in the herbage grazed by D cows were respectively lower and higher than that grazed by M cows ($P<0.05$). Plant species composition in the grazed herbage did not differ between treatments, although a greater proportion of clover was observed in the herbage grazed by M cows than that by D cows (7.7 vs 5.1 %DM).

Table 4.2: Mean values for botanical composition and nutritive value of the herbage grazed by dried-off (D) and milked (M) herds (mean \pm s.e.)

Components	Dried-off (D)	Milked (M)	sig ¹
<u>Dry matter (DM), live and dead material contents:</u>			
Dry Matter (%)	21.1 \pm 0.3	16.7 \pm 0.3	***
Live (%DM)	77.5 \pm 2.8	89.1 \pm 2.8	*
Dead (%DM)	22.5 \pm 2.8	10.9 \pm 2.8	*
<u>Species composition (%DM):</u>			
Perennial ryegrass	70.0 \pm 3.5	65.0 \pm 3.5	ns
Cocksfoot	22.1 \pm 3.0	25.4 \pm 3.0	ns
White clover	5.1 \pm 1.3	7.7 \pm 1.3	ns
Other species	2.8 \pm 0.7	1.9 \pm 0.7	ns
<u>Nutritive value (ME concentration, M/D and Crude Protein, CP):</u>			
M/D (MJ ME/kg DM)	10.1 \pm 0.4	11.1 \pm 0.4	ns
CP (%DM)	22.6 \pm 0.4	25.4 \pm 0.4	**

¹ Significance of difference: ** $P>0.05$; * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

The M pastures contained higher concentrations of ME (11.1 vs 10.1 MJ ME/kg DM) and CP (25.4 vs 22.6 %DM) than the D herbage; the difference in ME was not significant ($P>0.05$), whereas the difference in CP was significant ($P<0.01$).

Silage dry matter content was on average 34 (± 1.2) percent. Its content of crude protein was 13.2 (± 0.9) %DM, and the M/D value was 9.0 (± 0.30) MJ ME/kg DM (see Table 3.2).

4.3 Live weight and body condition score

The mean values of live weight (LW) and body condition score (CS) for the three dates of measurement (beginning, middle and end of the experimental period) are shown in Table 4.3; and the corresponding LW gain (LW Δ) and CS gain (CS Δ) (after adjustment by covariate effects, see Section 3.5) are shown in Table 4.4.

At the start of the experiment, D cows were significantly ($P<0.001$) lighter (452 vs 484 kg LW) than their counterpart M cows. The fact that low milk yield was one of the major criteria for the drying-off decision determined that most of the younger cows with low live weights were dried-off on 4th April. Nevertheless, cows on both systems of management did not differ ($P>0.05$) in body condition score at the start of the experiment.

At the mid point of the experimental period, treatments differed significantly in LW ($P<0.001$) and CS ($P<0.01$). D cows continued to be lighter (478 vs 512 kg LW), but fatter (4.86 vs 4.57 CS units) than the M cows. At the end of the experiment, D cows were significantly ($P<0.05$) lighter (499 vs 519 kg LW), but significantly ($P<0.001$) fatter (5.06 vs 4.62 CS units) than the M cows.

Both groups of cows gained LW and CS during the experimental period (Table 4.4; Figure 4.4). The rate of LW Δ and CS Δ by D cows were significantly faster than those of the M cows ($P<0.01$), except for LW Δ in the first half of the experimental period (Table 4.4).

Table 4.3: Mean values for live weight (LW, kg/cow) and condition score (CS, scale 1 to 10 units/cow) for dried-off (D) and milked (M) cows (mean±s.e.)

Period of the experiment	Dried-off (D)	Milked (M)	sig ¹
A. Beginning (Day 0; 4th April):			
LW	452±6	484±6	***
CS	4.43±0.08	4.29±0.07	ns
B. Mid (Day 27; 2nd May):			
LW	478±7	512±6	***
CS	4.86±0.08	4.57±0.07	**
C. End (Day 54; 29th May):			
LW	499±7	519±6	*
CS	5.06±0.08	4.62±0.08	***

¹ Significance of difference: *P>0.05; *P<0.05; **P<0.01; ***P<0.001.

Table 4.4: Mean values for live weight gain (LW Δ, kg/cow) and condition score gain (CS Δ, 1 to 10 units/cow) for dried-off (D) and milked (M) cows throughout the experimental period (mean±s.e.)

Period of the experiment	Dried-off (D)	Milked (M)	sig ¹
A. Beginning to Mid (27 days):			
LW Δ	27.2±1.6	27.2±1.4	ns
CS Δ	0.44±0.05	0.27±0.04	**
B. Mid to End (27 days):			
LW Δ	21.7±1.7	6.4±1.5	***
CS Δ	0.24±0.05	0.02±0.05	**
C. Beginning to End (54 days):			
LW Δ	48.9±2.0	33.6±1.8	***
CS Δ	0.64±0.06	0.31±0.05	***

¹ Significance of difference: *P>0.05; **P<0.01; ***P<0.001.

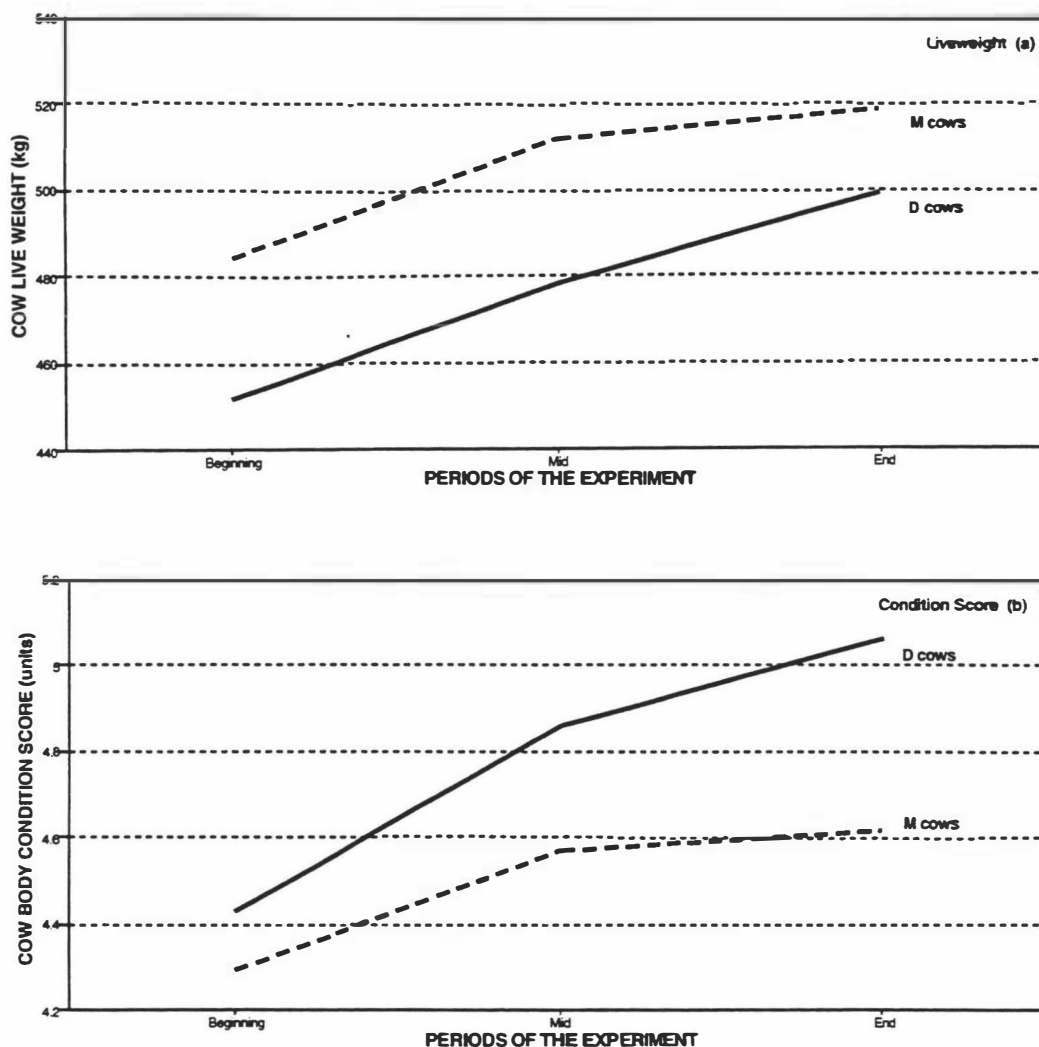


Figure 4.4: Mean values for cow live weight (LW, kg) (a) and cow body condition score (CS, units) (b) for dried-off (D) and milked (M) treatments throughout the experimental period

4.4 Milk yield

Table 4.5 and Figure 4.5 show the milk yields produced by the M cows throughout the experimental period. Slight increases in milk fat (MF), milk protein (MP) and milksolids (MS, fat+protein) yields were observed around the third to fifth weeks of the experimental period, following which they decreased until the end of the experimental period.

Table 4.5: Mean values for daily milk fat (MF), milk protein (MP) and milksolids (MS, MF+MP) yields (kg/cow/day) and total yields (kg/cow) for the milked (M) treatment (mean±s.d.)

	Milk fat (MF)	Milk protein (MP)	Milk solids (MS=MF+MP)
Daily yields in each week:			
week 1	0.68±0.12	0.46±0.08	1.14±0.19
week 2	0.61±0.09	0.52±0.07	1.13±0.16
week 3	0.68±0.10	0.51±0.06	1.19±0.15
week 4	0.65±0.10	0.50±0.06	1.15±0.16
week 5	0.66±0.10	0.51±0.07	1.17±0.16
week 6	0.57±0.11	0.42±0.07	0.99±0.17
week 7	0.52±0.12	0.39±0.09	0.91±0.21
week 8	0.48±0.13	0.34±0.09	0.82±0.21
overall	0.61±0.08	0.46±0.05	1.07±0.13
Total yields (54 days):			
	32.8±5.1	24.9±3.4	57.7±8.2

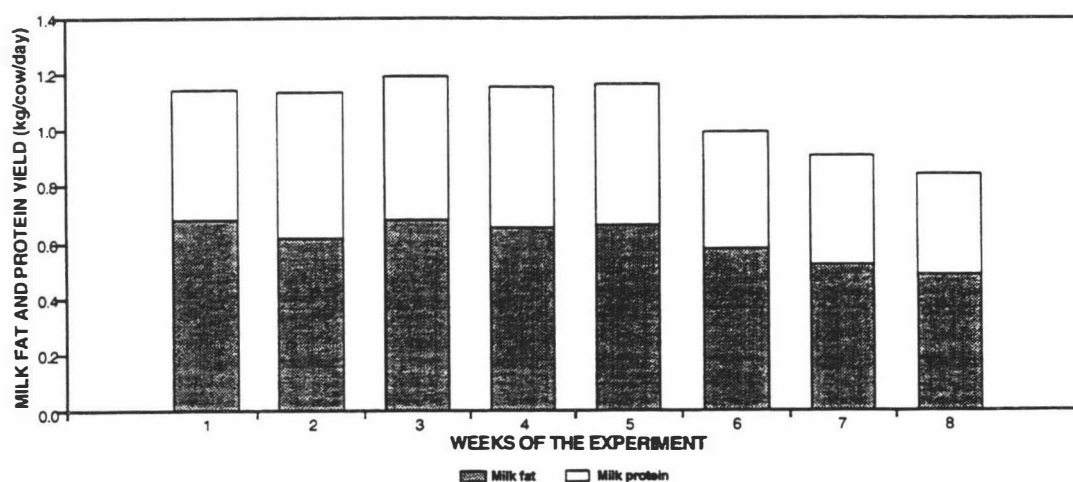


Figure 4.5: Mean daily milk fat (kg MF/cow/day), milk protein (kg MP/cow/day) and milksolids (MF+MP, kg MS/cow/day) yields of the milked (M) cows throughout the experimental period

4.5 Average pasture cover

Table 4.6 and Figure 4.6 show the effects of treatments on the average pasture cover (APC) throughout the experimental period. The APC in the D farmlets was significantly higher from the day 21st onwards than those of the M farmlets. The APC decreased during the experimental period for both treatments (Figure 4.7), but the magnitude of this decrease was significantly greater (-633 vs -49 kg DM/ha) on the M farmlets than on the D farmlets ($P < 0.01$); mainly due to the decrease in cover on the M farmlets between day 7 and 21 (Table 4.6).

Table 4.6: Mean values for average pasture cover (APC, kg DM/ha) and their changes (kg DM/ha) during the experimental period (mean \pm s.e.)

	Dried-off (D)	Milked (M)	sig ¹
Average pasture cover (APC, kg DM/ha):			
Day 0 (start)	2231 \pm 18	2228 \pm 18	ns
Day 7	2560 \pm 23	2429 \pm 23	ns
Day 21	2610 \pm 20	1906 \pm 20	**
Day 35	2259 \pm 29	1561 \pm 29	**
Day 54 (end)	2182 \pm 73	1595 \pm 73	*
Changes in APC (kg DM/ha):			
Day 0 to Day 7	329 \pm 40	201 \pm 40	ns
Day 7 to Day 21 ²	51 \pm 9	-523 \pm 9	***
Day 21 to Day 35	-352 \pm 48	-345 \pm 48	ns
Day 35 to Day 54	-77 \pm 65	32 \pm 65	ns
Day 0 to Day 54	-49 \pm 61	-633 \pm 61	**

¹ Significance of difference: ns $P > 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

² Silage was not given to M herds in this period.

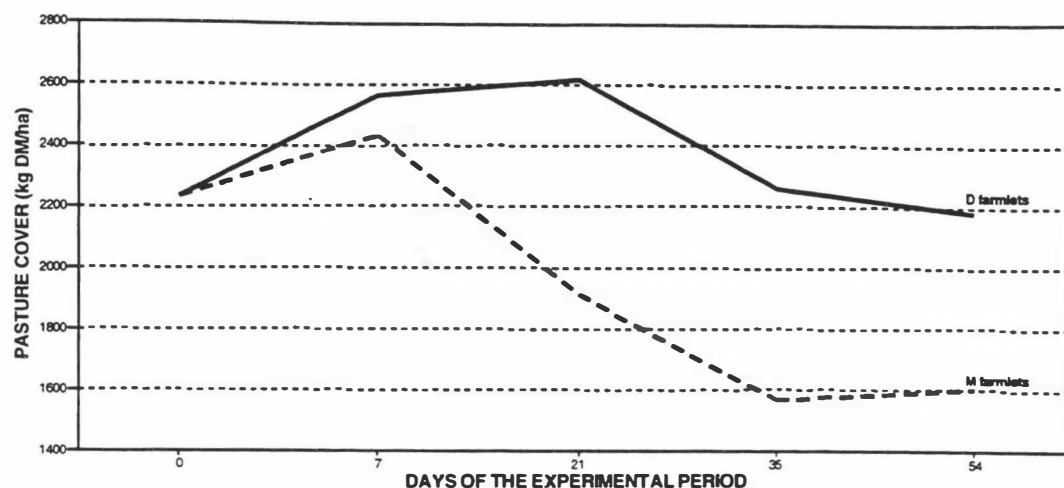


Figure 4.6: Mean values for the average pasture cover (APC, kg DM/ha) on the Dried-off (D) and Milked (M) farmlets throughout the experimental period

4.6 Final conditions for animal and pasture conditions versus the targeted values, and total effects of the treatments

Table 4.7 summarizes the final conditions in condition score (CS) and average pasture cover (APC) and their respective changes throughout the experimental period. The effects of the systems of management on CS and APC measured at the end of the experiment were statistically significant. The conditions on the D farmlets were close to the original targets (i.e. 2000 kg DM/ha APC and 5.0 units CS). On the other hand, for the M farmlets, conditions were well below the targeted values (by 405 kg DM/ha APC, and 0.38 units CS/cow).

During the 54 day period, the M herds were given 295 kg silage DM/cow and produced 57.7 kg MS/cow (32.8 kg MF/cow) (Table 4.7). However, the extra 54 days in milk of M herds were associated with less gain in CS (by 0.33 units CS/cow), but a greater loss of APC (by -584 kg DM/ha APC) when compared with those of the D herds (Table 4.7).

Table 4.7: Mean values for final animal and pasture conditions and total silage fed and milk yields, changes in condition score (CS Δ) and average pasture cover (APC Δ) during the 54 days of the experiment (mean \pm s.e.¹)

	Dried-off (D)	Milked (M)	sig ²
Final conditions (29th May):			
Condition score (CS, 1 to 10 units/cow)	5.06 \pm 0.08	4.62 \pm 0.08	***
Average pasture cover (APC, kg DM/ha)	2182 \pm 73	1595 \pm 73	*
Totals for 54 days:			
Silage fed (kg DM/cow)	0	295 \pm 5	
Silage fed (kg equivalent pasture DM/cow) ³	0	241 \pm 4	
Milk solids produced (kg MS/cow)	0	57.7 \pm 8.2	
Milk fat produced (kg MF/cow)	0	32.8 \pm 5.1	
CS Δ (1 to 10 units/cow)	0.64 \pm 0.06	0.31 \pm 0.05	***
APC Δ (kg DM/ha)	-49 \pm 61	-633 \pm 61	*

¹ mean \pm s.d., for silage fed, milk solids and milk fat yields.

² Significance of difference: *P<0.05; ***P<0.001.

³ Calculated on basis of ME contents of silage and pasture on M treatment (Tables 3.2 and 4.2).

4.7 Regression analyses of the daily apparent herbage intake on herbage allowance, pre-grazing herbage mass and residual herbage mass

Table 4.8 shows the best fitting regression models for apparent herbage dry matter intake (AHDMI) of D and M cows, in terms of their herbage dry matter allowance (HDMA), pre-grazing herbage mass (PGHM) and residual herbage mass (RHM) conditions; and Figures 4.7a, 4.7b and 4.7c show the respective regression lines. For both the D and M cows, the AHDMI were strongly and linearly related to the HDMA (Equation 4.1 and 4.2, respectively). This relation was larger in the D cows than in the M cows (Figure 4.7a). On the other hand, the AHDMI of both the D and M cows were positive and curvilinearly related to their respective PGHMs (Figure 4.7b) and RHMs (Figure 4.7c). The quadratic component of these influences were negative and weak for the D cows (Equations 4.3 and 4.5); whereas they were positive and strong for the M cows (Equations 4.4 and 4.6).

Table 4.8: Results of simple and multiple regression analyses of apparent herbage intake (AHDMI, kg DM/cow/day) on herbage allowance (HDMA, kg DM/cow/day), pre-grazing herbage mass (PGHM, t DM/ha) and residual herbage mass (RHM, t DM/ha) for dried-off (D) and milked (M) cows

Estimates (mean±s.e.)	Probability ¹
<u>A. Regression on Herbage DM Allowance (HDMA, kg DM/cow/day):</u>	
<i>D cows: AHDMI_D=β₁(HDMA_D); R²=0.99 (P<0.0001)</i>	<i>Eq. 4.1</i>
$\beta_1 = 0.71 \pm 0.02$	P<0.0001
<i>M cows: AHDMI_M=β₁(HDMA_M); R²=0.98 (P<0.0001)</i>	<i>Eq. 4.2</i>
$\beta_1 = 0.48 \pm 0.01$	P<0.0001
<u>B. Regression on Pre-grazing Herbage Mass (PGHM, t DM/ha):</u>	
<i>D cows: AHDMI_D=β₁(PGHM_D)+β₂(PGHM_D)²; R²=0.99(P<0.0001)</i>	<i>Eq. 4.3</i>
$\beta_1 = 4.46 \pm 0.58$	P<0.0001
$\beta_2 = -0.31 \pm 0.16$	P>0.05
<i>M cows: AHDMI_M=β₁(PGHM_M)+β₂(PGHM_M)²; R²=0.99(P<0.0001)</i>	<i>Eq. 4.4</i>
$\beta_1 = -0.21 \pm 1.11$	P>0.05
$\beta_2 = 1.95 \pm 0.39$	P<0.001
<u>C. Regression on Residual Herbage Mass (RHM, t DM/ha):</u>	
<i>D cows: AHDMI_D=β₁(RHM_D)+β₂(RHM_D)²; R²=0.98 (P<0.0001)</i>	<i>Eq. 4.5</i>
$\beta_1 = 16.85 \pm 5.11$	P<0.01
$\beta_2 = -5.47 \pm 4.84$	P>0.05
<i>M cows: AHDMI_M=β₁(RHM_M)+β₂(RHM_M)²; R²=0.97(P<0.0001)</i>	<i>Eq. 4.6</i>
$\beta_1 = -2.92 \pm 4.68$	P>0.05
$\beta_2 = 9.02 \pm 3.22$	P<0.05
<u>D. Regression on HDMA (kg DM/cow/day), PGHM (t DM/ha) & RHM (t DM/ha):</u>	
<i>D cows: AHDMI_D=β₁(HDMA_D)+β₂(PGHM_D)²; R²=0.99 (P<0.0001).....</i>	<i>Eq. 4.7</i>
$\beta_1 = 0.50 \pm 0.05$	P<0.0001
$\beta_2 = 0.28 \pm 0.06$	P<0.001
<i>M cows: AHDMI_M=β₁(HDMA_M)+β₂(PGHM_M)+β₃(RHM_M); R²=0.99(P<0.0001)</i>	<i>Eq. 4.8</i>
$\beta_1 = 0.44 \pm 0.03$	P<0.0001
$\beta_2 = 6.77 \pm 0.69$	P<0.0001
$\beta_3 = -12.23 \pm 1.42$	P<0.0001

¹ Probability (P) value of estimates as derived from "t" test.

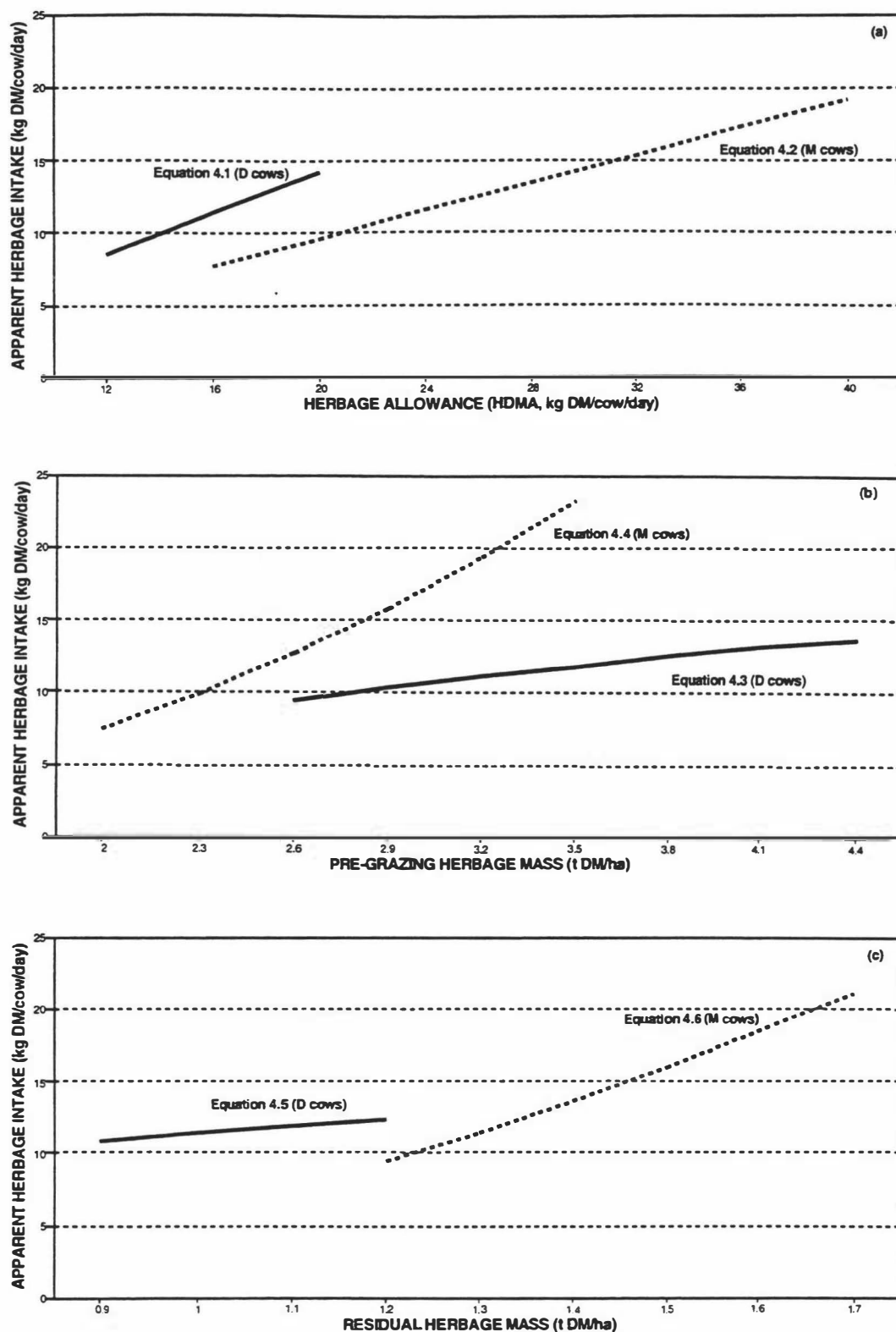


Figure 4.7: Regression lines of apparent herbage intake (AHDMI, kg DM/cow/day) on herbage allowance (HDMA, kg DM/cow/day) (a), pre-grazing herbage mass (PGHM, t DM/ha) (b), and residual herbage mass (RHM, t DM/cow/day) (c) for dried-off (D) and milked (M) cows

When the joint effects of HDMA, PGHM and RHM were considered, the AHDMI of D cows was additively affected by the linear effect of the HDMA and the quadratic effect of PGHM (Equation 4.7); whereas the AHDMI of the M cows was linearly affected by the additive effect of the HDMA and PGHM and the negative effect of RHM (Equation 4.8).

4.8 Feeding behaviour

Table 4.9 shows the grazing conditions and the feeding behaviour of the experimental cows for the 17th May and 24th May. Additionally, data for grazing conditions and feeding behaviour for the two dates (17th and 24th May) were compared independently for D and M cows, and the results are shown in Table 4.10. Note that the cows in the M treatment were silage supplemented (M-S) on 17th May (silage was fed at 11.00 hours) and not supplemented (M-U) on 24th May. On both dates of feeding behaviour assessment, all of the four herds were given access to the fresh daily break of pasture at about 07.30 hours.

On 17th May, when the M cows were silage supplemented (M-S) and offered a lower PGHM, but with a higher HDMA, the AHDMI did not differ significantly ($P>0.05$) between treatments, although the D cows left lower RHM (631 vs 1233 kg DM/ha) than the M-S cows (Table 4.9). Under these conditions, grazing (G) and ruminating (R) activities did not differ ($P>0.05$) between treatments, although D cows spent more time (10.1 vs 8.5 hours/day) on other activities (O, no-feeding related activities). During the first 8 hours after the start of grazing on a fresh area of pasture, the D cows carried out a greater proportion (90.6 vs 71.3 %) of their total G time than M-S cows. On the other hand, D cows carried out smaller (88.3 vs 93.0%) and greater (79.0 vs 61.8%) proportions of their R and O times, respectively, in the remaining 14 hours following the sunset, than the M-S cows. Except for the rate of biting measured at 16.00 hours, the rate of biting of the D cows were significantly lower than that of the M-S cows throughout the daylight hours; the overall mean rates of biting were 44.8 and 56.8 bites/min for D and M-S cows, respectively (Table 4.9).

Table 4.9: Mean values for feeding behaviour of Dried-off (D) and Milked (M) cows, measured on 17th May (when M cows were silage supplemented, M-S) and 24th May (when M cows were not silage supplemented, M-U) (comparisons between treatments for each day of measurement)(mean±s.e.)¹

	17 th May		24 th May		s.e.
	Dried-off (D)	Milked (M-S)	Dried-off (D)	Milked (M-U)	
<u>Daily grazing conditions and apparent intakes²:</u>					
PGHM (kg DM/ha)	4534 ^a	3252 ^b	4700 ^c	3468 ^d	41
RHM (kg DM/ha)	631 ^a	1233 ^b	801 ^c	1264 ^d	51
HDMA (kg DM/cow)	15.6 ^a	26.3 ^b	16.5 ^c	36.8 ^d	4.3
AHDMI (kg DM/cow)	13.5 ^a	16.3 ^a	13.7 ^c	23.4 ^d	0.5
<u>Feeding activities (hours spent in 24 hours):</u>					
Grazing (G)	6.6 ^a	5.7 ^a	7.4 ^c	9.3 ^d	0.1
Silage eating (S)	0	2.5	0	0	0.0
Ruminating (R)	7.3 ^a	7.4 ^a	7.0 ^c	6.1 ^c	0.2
Other (O)	10.1 ^a	8.5 ^b	9.6 ^c	8.6 ^c	0.2
<u>Temporal distribution of activities (% of the total activity):</u>					
G in first 8 h ³	90.6 ^a	71.3 ^b	83.0 ^c	69.0 ^d	1.9
R after sunset ⁴	88.3 ^a	93.0 ^b	89.1 ^c	93.8 ^c	1.0
O after sunset ⁴	79.0 ^a	61.8 ^b	78.6 ^c	79.8 ^c	0.8
<u>Rate of biting (bites/min):</u>					
At 07.30 hours	47.5 ^a	63.0 ^b	52.5 ^c	56.0 ^c	2.3
At 09.00 hours	52.5 ^a	63.5 ^b	48.5 ^c	52.5 ^c	1.8
At 12.00 hours	37.0 ^a	48.5 ^b	36.5 ^c	46.5 ^c	2.7
At 16.00 hours	40.5 ^a	52.0 ^a	32.5 ^c	54.5 ^d	3.0
Overall	44.8 ^a	56.8 ^b	42.5 ^c	52.4 ^d	2.6

¹ Two independent set of comparisons between treatments (one for each day of measurement). Significance of comparisons between D and M-S on 17th May are notated by subscript letters ^a and ^b; whereas the significance of comparisons between D and M-U on 24th May are notated by subscript letters ^c and ^d. For each set of comparisons, rows with different single subscripts are significantly different (P<0.05).

² See List of abbreviations

³ % of the total G activity spent in the following 7 h after start of grazing (07.30 hours).

⁴ % of the total R or O activity spent during the period from 17.30 to 07.30 hours.

Table 4.10: Mean values for feeding behaviour of Dried-off (D) and Milked (M) cows, measured on 17th May and 24th May (comparisons between days of measurement for each treatment)(mean±s.e.)¹

	Dried-off (D)		Milked (M)		s.e.
	17 th May	24 th May	17 th May (M-S)	24 th May (M-U)	
<u>Daily grazing conditions and apparent intakes²:</u>					
PGHM (kg DM/ha)	4534 ^a	4700 ^a	3252 ^c	3468 ^c	41
RHM (kg DM/ha)	631 ^a	801 ^a	1233 ^c	1264 ^c	51
HDMA (kg DM/cow)	15.6 ^a	16.5 ^a	26.3 ^c	36.8 ^d	4.3
AHDMI (kg DM/cow)	13.5 ^a	13.7 ^a	16.3 ^c	23.4 ^d	0.5
<u>Feeding activities (hours spent in 24 hours):</u>					
Grazing (G)	6.6 ^a	7.4 ^b	5.7 ^c	9.3 ^d	0.1
Silage eating (S)	0	0	2.5	0	0.0
Ruminating (R)	7.3 ^a	7.0 ^a	7.4 ^c	6.1 ^d	0.2
Other (O)	10.1 ^a	9.6 ^a	8.5 ^c	8.6 ^c	0.2
<u>Temporal distribution of activities (% of the total activity):</u>					
G in first 8 h ³	90.6 ^a	83.0 ^b	71.3 ^c	69.0 ^c	1.9
R after sunset ⁴	88.3 ^a	89.1 ^a	93.0 ^c	93.8 ^c	1.0
O after sunset ⁴	79.0 ^a	78.6 ^a	61.8 ^c	79.8 ^d	0.8
<u>Rate of biting (bites/min):</u>					
At 07.30 hours	47.5 ^a	52.5 ^a	63.0 ^c	56.0 ^c	2.3
At 09.00 hours	52.5 ^a	48.5 ^b	63.5 ^c	52.5 ^d	1.8
At 12.00 hours	37.0 ^a	36.5 ^a	48.5 ^c	46.5 ^c	2.7
At 16.00 hours	40.5 ^a	32.5 ^a	52.0 ^c	54.5 ^c	3.0
Overall	44.8 ^a	42.5 ^a	56.8 ^c	52.4 ^c	2.6

¹ Two independent set of comparisons between days (17th and 24th May) of measurement (one for D cows and another for M cows). Significance of comparisons between days of measurement for D cows are notated by subscript letters ^a and ^b; whereas the significance of comparisons between days of measurement for M cows (i.e. M-S vs M-U) are notated by subscript letters ^c and ^d. For each set of comparisons, rows with different single subscripts are significantly different (P<0.05).

² See List of abbreviations

³ % of the total G activity spent in the following 7 h after start of grazing (07.30 hours).

⁴ % of the total R or O activity spent during the period from 17.30 to 07.30 hours.

On 24th May, when silage was not fed to M cows (M-U) (Table 4.9), and when PGHM and HDMA of the grazed pastures significantly differed between treatments, the AHDMI of the D cows was significantly lower (13.7 vs 23.4 kg DM/cow/day) than that of M-U cows and they left lower RHM (801 vs 1264 kg DM/ha) than the M-U cows. Under these conditions, D cows spent less time (7.4 vs 9.3 h) in G activity than the M-U cows. However the total time devoted to R and O activities were not different ($P>0.05$) between treatments. The M-U cows carried out a smaller proportion (69 vs 83%) of their total G time during the first 8 hours after the start of grazing on a fresh area, than the D cows. The temporal distribution (% after the sunset) of R and O activities did not differ between the treatments. The rate of biting did not differ between the treatments except for that measured at the 16.00 hours ($P<0.05$). Nevertheless, the overall biting rate of the D cows was significantly lower (42.5 vs 52.4 bites/min) than that of M-U cows (Table 4.9).

Table 4.10 shows that the grazing conditions and the feeding behaviour of the D cows were very similar on both dates of measurement (17th and 24th May), except for G time, G in the first 8 hours after the start of grazing on a new area, and the rate of biting at 09.00 hours.

Finally, when the Milked (M) cows, either silage supplemented (M-S, 17th May) or not silage supplemented (M-U, 24th May), were compared under similar PGHM, but different HDMA (Table 4.10), significantly lower (16.3 vs 23.4 kg DM/cow/day) apparent herbage intake (AHDMI) and grazing time (5.7 vs 9.3 h) were observed when silage was given than when silage was not given. However, the M-S cows spent more R time (7.4 vs 6.1 h) than the M-U cows. Time devoted to O activities were similar under both conditions. The temporal distribution of G and R activities were similar for both conditions, but the M-S cows carried out a smaller proportion (61.8 vs 79.8%) of their O activities in the 14 h after the sunset than when they were not supplemented (M-U). Biting rate was similar for both feeding conditions, except at 09.00 hours (Table 4.10).

CHAPTER FIVE

DISCUSSION

5.1 Feed intake

Table 5.1 shows the theoretical calculated ME requirements and the total apparent ME intake measured for the total experimental period. The total apparent feed intakes of the D cows and M cows were overestimated by about 15 and 26%. The HDMD technique (see Section 3.4.4) used to estimate herbage intake has been associated with underestimation of the residual mass, due to trampling (Meijs 1981). In addition, wastage of silage, which was not measured, was another probable reason for the overestimation of total intakes by the M cows.

Table 5.1: Comparison between the theoretical calculated daily energy requirements (MJ ME/cow/day) and the measured values of daily intake (MJ ME/cow/day) for dried-off (D) and milked (M) cows

	Dried-off (D)	Milked (M)
<u>Calculated Metabolisable Energy requirements (MJ ME/cow/day):</u>		
Maintenance ¹	56	63
Liveweight gain ²	40	20
Milk production ³	0	76
Pregnancy ⁴	4	4
T O T A L	100	163
<u>Total apparent intake measured (TAMEI, MJ ME/cow/day):</u>		
T O T A L ⁵	115	206
<u>Overestimation of daily ME intake measurements:</u>		
Overestimation (%)	14.6	26.3

¹ Calculated in basis of Fasting heat production (plus activity allowance) of 0.39 and 0.43 MJME/kg LW^{0.75} (Brookes 1994) and k_m of 0.72 and 0.70 (ARC 1980), respectively for D and M cows.

² Calculated in basis of NE_{gain} of 19 MJ/kg LW gain (AFRC 1993) and k_g of 0.43 and 0.59 (ARC 1980) for D and M cows, respectively.

³ Calculated in basis of NE of 79 MJ/kg milk fat (Holmes *et al.* 1987) and k_l of 0.63 (AFRC 1990)

⁴ Based on Gompertz equations (ARC 1980), average for between 124 and 178 days of pregnancy.

⁵ Daily TAMEI, from Table 4.1.

5.2 Effects of the treatments on final animal and pasture conditions, and total effects on the system

5.2.1 Milk production

During the 54-day period the M cows produced 57.7 kg MS/cow (32.8 kg MF/cow), corresponding to a daily overall average of 1.07 kg MS/cow (0.61 kg MF/cow) (Table 4.5). This level of production is relatively higher than that (0.93 kg MS/cow/day) reported in later lactation by Clark (1993) but lower than that (1.25 kg MS/cow/day) by Holmes *et al.* (1994). The differences may be attributed to the associated live weight change and differences in feeding level.

It is well established that the proportion of dietary energy partitioned towards milk production decreases as lactation progresses (Broster and Thomas 1981; Trigg *et al.* 1983). This marginal partition was not measured in the present experiment, but a *total partitioning of the feed energy* (above maintenance and pregnancy) to milk production of 80% (76/96) was calculated for the data (for M cows) presented in Table 5.1. This value is similar compared to those (above 85%) calculated for other late lactation supplementary feeding studies (Bryant 1978; King and Stockdale 1982; Clark 1993; Holmes *et al.* 1994; Penno *et al.* 1995). For the experiment carried by King and Stockdale (1982), the extra (marginal) energy partitioned to milk production was 50%; being this value higher than that (30%) calculated by Holmes (1995c) for the late lactation feeding trial carried out by Grainger (1990), but lower than that (60%) reported by Bryant and MacDonald (1987) for summer silage feeding. One of the major reasons for these high total partitioning of the feed energy to milk production at this stage of the lactation may be attributed to the relatively low feeding level, but also the genetic merit of the cows may be implicated. Undoubtedly, the partitioning to live weight gain will increase at higher feeding levels.

From the above figures, it can be suggested that at the stage of lactation at which the experiment was carried out (220 to 274 days in milk), there was still a

relatively large partitioning of energy intake towards milk production. This potential for milk production and the fixed costs of maintenance (irrespective of whether cows are dry or lactating) are two major factors contributing to the low annual efficiency of conversion of feed into milk in the seasonal dairying system, where herds are dried-off at earlier dates. Accordingly, Penno *et al.* (1995) have suggested that the effect of supplementary feeding on achievable days in milk in mid and late lactation, is more important than the stage of lactation effects on the changes in partitioning of extra feed energy to milk production.

5.2.2 Final cow condition score and average pasture cover versus the targeted values

As mentioned in Section 3.3, treatments in this experiment were planned to have common targets of 2000 kg/ha average pasture cover (APC) and 5.0 condition score (CS) at the end of the experiment (29th May). The final conditions on the D system were close to the target values; whereas, these targets were not achieved by the M treatment (see Table 4.7).

Final APC conditions on the dried-off (D) system was associated with under-utilization of the pasture grown. In fact, due to the restricted feeding levels (small areas grazed daily and long rotation lengths), pasture accumulated excessively, which undoubtedly lead to higher rates of decay and senescence (Hodgson 1990) and reduction in the quality of herbage grazed (see Table 4.2). Thus, for the particular pasture growth rates observed in April and May 1995, the drying-off date (4th April) for this treatment was probably at least 3 weeks earlier than it should have been (see APC, Table 4.6).

The lack of success in achieving the target APC value by the M system was mainly due to the higher herbage intake than that planned; and it occurred in the following manner: First, during the second and third week of the experimental period (April 1995), pasture growth rates were exceptionally high compared to what had been expected, and therefore the M cows were given high herbage

allowances (see Figure 4.2b) and no silage was fed during this period (see Figure 4.1). Consequently, their CSs (Figure 4.4b) and milk yields (Figure 4.5) increased in this period, but pasture cover (APC) on their farmlets decreased dramatically (by 523 kg DM/ha, see Table 4.6), which was not detected for two weeks (APC measured at intervals of two weeks). Second, even though the daily herbage allowance (HDMA) decreased from the third to fifth weeks of the experimental period (see Figure 4.2b); it was still high. Consequently, the APC continued to decrease (by 345 kg DM/ha), although milk yield and CS were maintained.

At the end of the experiment, the CS of D cows was close to the common targets at calving (5.0-5.5) (Parker *et al.* 1995); whereas that of M cows fell below the critical level (4.5) suggested for the end of the lactation (Bryant 1990a).

Consequently, the M cows would have to gain between 0.38 to 0.88 CS during the 2 months dry-off period in order to meet the calving target. Obviously, since the pasture cover on the 29th May was also below the calving targets (2 t DM/ha), these gains in CS must be achieved by off-farm wintering (Clark *et al.* 1994).

In line with previous silage feeding trials in the summer (Bryant and MacDonald 1987) and autumn (Clark 1993; Holmes *et al.* 1994), the extra days in milk achieved in this experiment was not associated with losses in LW or CS, but with decreased LW and CS gains. However the failure to achieve the target CS (5 CS) by the M cows, may be explained in terms of their relatively greater total partitioning of the energy intake (above maintenance and pregnancy requirements) to milk production rather than to live weight gain, as outlined in Section 5.2.1; which appears to be highly related to the feeding level. Thus, even higher levels of feeding (than those which were given) would had been required in order to meet the target CS and simultaneously produce milk. Undoubtedly, this approach would cause even larger decreases in average pasture cover, unless greater amounts of good quality silage were provided. Alternatively, by ending the lactation, the M cows would require high levels of feeding to replace the deficits in CS (Holmes *et al.* 1987), but this approach is expensive in terms of energy conversion (ARC 1980; King and Stockdale 1982). Finally, the rate of CS change

found in this experiment and the previous late lactation studies (Bryant 1978; King and Stockdale 1982; Bryant and MacDonald 1987; Clark 1993; Holmes *et al* 1994; Penno *et al.* 1995), suggest that CS of about 4.8 at the end of May would be more achievable than the CS 5.

Theoretically, the CS and APC targets could have been met in the following way: First, an extra 170 kg silage DM/cow would have been provided in order to avoid the 405 kg pasture DM/ha deficit in APC (at 2.9 cows/ha SR). Second, another extra 63 kg silage DM/cow would have been provided in order to avoid the 0.38 units CS/cow deficit, assuming that 137 kg pasture DM is required above maintenance to gain 1 CS by lactating dairy cows (King and Stockdale 1982). Thus, the M cows would have had to eat 21 kg DM daily (TADMI); i.e. 11 kg herbage DM (AHDMI) plus 10 kg silage DM. Undoubtedly, at this level of silage feeding, silage wastage could be high and likely could offset any economical benefit. Stockdale (1995) found linear milk production responses to maize silage feeding (up to 12 kg DM/cow/day) in late lactation; and suggested that at this stage milk yield is primarily energy-limited. Note that our calculations are apparent intakes, which probably overestimate the theoretical requirements by about 26% (see Section 5.1).

In practice, however, the more feasible farm management in late lactation would be to feed supplement and extend the lactation for only part of the herd, involving cows in reasonable body condition (e.g. above 4.5 CS) and milk yields (above 1 kg MS/cow). Then, both herds (dried-off and milked) should be managed separately, but to common targets of pasture cover (2000 kg DM/ha) and condition score (4.8 units/cow). For these purposes, the stocking rate of the dried-off herd should be high (compared to that of the present experiment) enough to avoid excessive accumulation of pasture. On the other hand, the milking herd should be generously fed at a lower SR (compared to that of the present experiment), but avoiding reduction in pasture cover by silage feeding. The leaders/followers grazing system (Mayne *et al.* 1986) might also be appropriate, with the milking cows being followed by the dried-off cows.

5.2.3 Total effects of the treatments

During the 54-day period, the M herds were given 295 kg silage DM/cow and produced 57.7 kg MS/cow (32.8 kg MF/cow) (Table 4.7), and the *short term, marginal response* to silage feeding (plus the losses of body condition and pasture cover) was 195 g MS or 111 g MF/kg silage DM. However, this simple index accounts neither for the inputs from lower CS and lost pasture cover, nor for the probable carryover effects on next season's milk production, caused by the lower final values for pasture cover (Bryant and MacDonald 1983; Thomson *et al.* 1993) and condition score (Rogers *et al.* 1979; Bryant 1982; Holmes and Grainger 1982; Grainger *et al.* 1982) for the M treatment. Therefore an alternative index, the *total marginal response* of the whole farm system was calculated.

For this purpose, silage input and the deficits (when compared with the D cows) in CS and APC of the M cows, were all expressed in terms of their "pasture equivalences" based in the following assumptions: First, silage input per cow was equivalent to 241 kg pasture DM (see Table 4.7). Second, considering that a dry, pregnant dairy cow must eat between about 167 to 171 kg pasture DM, above maintenance to gain one CS (Holmes and Grainger 1982; Garcia-Muniz 1994), the M cows to regain 0.33 CS must eat an extra 55 kg DM per cow. Third, to regain the 584 kg DM/ha APC in the M farmlets, the M cows must eat an extra 200 kg DM/cow (at 2.9 cows/ha SR) as feed input. Thus, the calculated *total marginal response* to the silage feeding and extra days in milk was 116 g MS or 66 g MF/kg equivalent pasture DM ($57.7/(241+55+200)$).

The above calculated *total marginal response* is higher (by 24 g) than that reported by Holmes *et al.* (1994) for a similar experiment, but using a 50:50 mixture of grass silage and apple pomace. These responses are much higher than the *immediate marginal response* of 66 g MS/kg silage DM fed in late lactation (36 days), with 7 extra days in milk reported by Clark (1993), and also than those reported from conventional trials (Kellaway and Porta 1993). The fixed costs of maintenance, regardless of whether the cows are dry or lactating (King and

Stockdale 1982; Holmes and Brookes 1993) and the higher efficiency of ME conversion into LW gain by lactating cows than by dried-off cows (ARC 1980), are likely the major reasons for the increased responses to supplementary feeding at this stage.

The responses cited above and those reported for concentrate feeding evaluated in whole farm systems (McCallum *et al.* 1995; Penno *et al.* 1995; Stakelum *et al.* 1995) show a great potential for milk production in late lactation and are in contrast to previous beliefs (Stockdale *et al.* 1987; Stockdale and Trigg 1989; Kellaway and Porta 1993). In fact, the major benefit comes from achieving extra days in milk by the inclusion of extra feeding into a farming system. This potential would be maximized if high BI cows are continued milking for an extra 1 to 2 months by supplementary feeding.

5.3 Effects of sward conditions upon herbage intake

In this experiment, in the range in which daily herbage allowance (HDMA) was managed, its relationship to intake (AHDMI) was positive and linear for both D and M treatments (Figure 4.2a,b; Figure 4.7a). The increase in daily AHDMI achieved for every additional kg of HDMA was 0.71 and 0.48 kg DM/cow/day for D and M cows, respectively; these values being higher than the values (0.15 to 0.35 kg DM) reported by Stockdale (1985). The linear relationships found for the D treatment appear obvious, but that for the M treatment is contrary to those curvilinear relationships reported by other authors (Glassey *et al.* 1980; Meijs 1981; Meijs and Hoekstra 1984; Holmes 1987; Suksombat *et al.* 1994). Undoubtedly, other factors such as PGHM may be responsible for that, although a linear relationship was also found by Stockdale (1985).

Combellas and Hodgson (1979) and Hodgson (1990) have suggested that herbage intake is near to the maximum when the efficiency of grazing of the daily allowance is less than 50%. According to that, intakes of the D cows were well below their capacity (Figure 4.2a); whereas M cows ate close to their maximum

(Figure 4.2b), especially in the second and third weeks of the experimental period when silage was not offered (Figure 4.1).

In the present experiment, because of the differences in rotation length, the pre-grazing herbage mass (PGHM) increased by 48% (from 2.8 to 4.1 t DM/ha) for D treatment, whereas it decreased by 21% (from 2.9 to 2.3 t DM/ha) for the M treatment, during the period of the experiment. As expected, the increase in PGHM in the D treatment was associated with increased dead material and lower clover contents, and therefore diminished quality (see Table 4.2), whereas the opposite was observed in the M treatment.

In the range in which PGHM for D and M treatments were operated, the AHDMI was influenced in different ways (see Figures 4.3a,b; 4.7b). Thus, AHDMI of D cows increased as the PGHM increased although with weak diminishing returns; whereas for M cows, the AHDMI also increased, but with increasing returns, which is contrary to the expected asymptotic (with declining incremental increases) pattern of response (Combellas and Hodgson 1979; Meijs 1983). The declining incremental increases in herbage intake at high PGHMs have been related to decreased quality associated with increased maturity. Although the PGHM of M treatment was within the range in which intake is likely not affected by PGHM (Combellas and Hodgson 1979; Holmes 1987), it can be suggested that the improved herbage quality (Table 4.2) resulting from the short rotation lengths and lower PGHMs (Hodgson and Jamieson 1981) may be one of the reason for the increased incremental responses in AHDMI observed in this experiment.

The residual herbage masses (RHM) measured throughout the experimental period differed markedly between the treatments (Figure 4.3a,b), reflecting the restricted and generous feeding conditions of D and M cows, respectively. For both treatments, a positive relationships between RHM and AHDMI were found although with opposite trends (Figure 4.7c). These facts suggest that the relationship between RHM and AHDMI depends upon PGHM and HDMA.

When HDMA, PGHM and RHM were included in a multiple regression to determine the influence of these sward characteristics on herbage intake (AHDMI), the best fitting equations differed between the D and M treatments (see Equations 4.7 and 4.8, Table 4.8). Thus, herbage allowance was the predominant factor determining the AHDMI of both D and M cows, but its importance was greater for the D cows than for the M cows, where the other sward factors contributed significantly. No interaction between HDMA and PGHM was found as suggested by Meijs (1981).

Sward height has been suggested to have an important effect upon herbage intake due to its close relationship with bite size (Combellas and Hodgson 1979; Rook *et al.* 1994a). However in rotational grazing systems this factor may be of less importance than herbage allowance. The technique used to measure herbage mass in the present experiment measures the HM as a function of the compressed sward height. Thus, pre-grazing and post-grazing sward heights were 20.5 and 5.3; and 16 and 7.7 cm for D and M treatments, respectively. In both cases the residual sward heights (stubble height) were below the critical levels (10 cm) at which intake approaches the maximum, as suggested by Hodgson (1990).

Substitution of herbage intake by supplementary feeding is well documented. Meijs and Hoekstra (1984) suggested that the rate of substitution is primarily influenced by the level of herbage allowance. Unfortunately, because of the design of this experiment, substitution rate was not measured, but its effect on the system has been measured through its effect on average pasture cover as discussed later. Nevertheless, a brief discussion about this topic is given in Section 5.4.

5.4 Effects of grazing conditions and silage feeding upon feeding behaviour

5.4.1 Dried-off (D) versus Milked (M) cows

It is well established that under limiting sward conditions, the most readily apparent adaptive response to a decreasing bite size is an increase in grazing (G)

time (Hodgson 1985), but increases in both G time and rate of biting (BR) have also been suggested (Chacon *et al.* 1978; Jamieson and Hodgson 1979). In this experiment, harvesting efficiency (in one grazing) was higher for D cows than for M cows on both 17th (86 vs 62%) and 24th May (83 vs 64%), which is clear evidence for their restricted feeding levels compared to that of M cows. Although the total G time of the D cows was not increased; per kg of apparent herbage intake, D cows had not only larger G times (31 vs 23 min/kg AHDMI) but also larger R times (32 vs 24 min/kg AHDMI) than M cows. Furthermore, time devoted by D cows to other (O) activities was greater than that by M cows (Table 4.9). The increased R time observed in D cows was likely a consequence of the low quality herbage grazed by this group (Table 4.2). Bite size was not measured in this experiment, but it can be suggested that it decreased rapidly as sward height decreased (Forbes and Hodgson 1985; Flores *et al.* 1993).

Although the D cows were offered high PGHM, their hungry condition drove them to graze more continuously until a point where sward conditions imposed severe restriction to continued grazing; about 90% of their total G time was carried out during the first 8 hours after having been given access to the fresh grazing area, see Table 4.9. Consequently, these cows started their R and O activities at earlier times than M cows; and a very small proportion of their G and R activities were carried out during the remaining hours after sunset. The later suggests not only their unwillingness to extend G time beyond a point where sward conditions implies a relatively high cost of harvesting per unit of feed (Hodgson 1986; Rook *et al.* 1994), but also some kind of synchronized adaptation of their daily feeding behaviour to the daily pattern of herbage availability (Rook and Huckle 1995).

Contrary to expectations, BR of D cows was lower than that of M cows throughout the day (see Table 4.9). Three major facts may explain this finding: First, because of the higher stocking density (212 vs 95 cows/ha), cows in the D herds were under constant pressure from each other, which may have disturbed the

continuity of their grazing behaviour. Second, because of the higher PGHM, D cows initially spent more time in accommodating and masticating the larger mouthfuls of herbage (such as reported by Penning *et al.* 1991 for sheep). Third, as grazing progressed herbage was more contaminated by faeces and soil, increasing the time for searching clean bites. However, probably some increase in the BR did occur between 09.00 and 12.00 a.m. (before the sward conditions were highly limiting), but because of the interval between measurement periods, it was not detected.

5.4.2 Effects of supplement on feeding behaviour of milked (M) cows

It is well documented (Grainger and Mathews 1989; Kellaway and Porta 1993) that when supplements are fed to grazing animals, pasture intake is depressed (substitution effect). This effect was not measured in this experiment, but there are two pieces of evidence, which suggest that it occurred: First, neither the AHDMI, nor the G times differed between treatments on 17th May (when M cows were silage supplemented), but they significantly differed on 24th May (when M cows were not silage supplemented) (Table 4.9). Second, total G time differed between supplemented M cows (M-S) and un-supplemented M cows (M-U) (see Table 4.10), although G time per each kg of apparent herbage eaten were similar (21 and 23 min/kg AHDMI for M-S and M-U, respectively).

In this experiment the total time (8.2 h) devoted to grazing (G) plus eating silage (S) by M-S cows was similar to the G time (9.3 h) of M-U cows. This fact suggests that there was substitution of G time by S time. Furthermore, the lack of differences between M-S and M-U cows in their O (other activities) times and their rates of biting (see Table 4.10), agrees with the later suggestion. In fact, Leaver (1986) has indicated that substitution of herbage intake by supplementary feeding usually operates through reduction in G time.

Even though herbage allowance (HDMA) differed between the two measurement days (i.e. for M-S and M-U), the residual herbage masses were similar on both days (see Table 4.10). Therefore, based on the fact that the daily grazing efficiency (62 and 63%) and the G time spent per each kg AHDMI (21 and 23 min) were similar for both days, it can be suggested that the rate of substitution of G time for S time was around 1.0. Thus, a reduction of the daily G time by 27 min/kg silage DM given was estimated (2.5 h/5.5 kg DM), a value which is lower than that (43 min) reported by Mayne (1991), also for silage given as a supplement.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

In contrast to conventional supplementary feeding studies, this experiment measured the effects of two systems of seasonal dairy farm management in autumn. Effects of extended days in milk plus silage supplementation (M system) versus early drying-off (D system) were compared in a duplicated farmlet study.

Feeding management between dried-off (D) and milked and silage fed (M) cows differed markedly throughout the experimental period (54 days). D cows were fed at restricted levels on pasture only; whereas M cows were generously fed on pasture and silage. Herbage quality was lower for the D cows because of the higher herbage mass accumulated due to the longer rotation. Measurements of the total metabolisable energy intake were overestimated by 15 and 26% for D and M cows respectively; the major reason for this was probably the underestimation of the residual herbage mass, and the assumption that all silage given was eaten. Herbage allowance was the major sward condition which affected herbage intake, especially in D cows. Intake of M cows was also affected by the pre-grazing herbage mass. Residual herbage mass reflected the level of intake of M cows.

The extra 54 days in milk by the M cows and the 295 kg silage DM/cow given resulted in an extra 57.7 kg milksolids (MS, fat+protein)/cow, but lower body condition score and average pasture cover, i.e 195 g MS/kg silage DM *immediate marginal response*. However, this simple index does not account for the probable carryover effects on next season's milk production, caused by the lower final values for pasture cover and condition score for the M treatment. Therefore, an alternative index, the *total marginal response* of 116 g MS/kg equivalent pasture DM was calculated. This value was calculated taking into account the whole marginal feed input in the M system (including the "pasture equivalences" of the feed required to overcome deficits in pasture cover and condition score).

Proposed target conditions at the end of the experiment (2000 kg DM/ha pasture cover and 5 condition score per cow) were achieved by the D system, but not by the M system. M system had deficits of 400 kg DM/ha pasture cover and 0.38 units CS/cow. The deficit in CS may be attributed to the relatively high total partitioning of the energy intake (above maintenance and pregnancy) to milk production; whereas, the deficit in pasture cover was a direct effect of the higher herbage allowances than those planned. The poor quality of the silage fed may also have influenced the results.

At the restricted feeding levels at which D cows were grazed, increased grazing time was the only compensating mechanism for the decreased rate of intake. Increase in the rate of biting to limiting sward conditions was not detected, probably due to the longer intervals of feeding behaviour monitoring. D cows also increased their ruminating time, likely due to the lower quality of the herbage eaten, due to the increased herbage accumulation and lower residual herbage masses on the D farmlets.

Silage supplementation caused substitution of the herbage intake of the M cows. Herbage substitution operated throughout a reduction in grazing time. A reduction of grazing time of 27 min/kg silage DM given was calculated.

The findings of the present experiment and those of other farm system studies show that milk production response to supplementary feed given in autumn (late lactation) is higher than was commonly believed, provided that it is associated with extra days in milk. Nevertheless, feed planning and management must be especially vigilant to ensure that the extended lactation does not cause reduced body condition and pasture cover at the start of next season.

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