Ration balancing in New Zealand dairy farm management:

A case farm simulation study

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Abstract

New Zealand dairy farmers are amongst the most cost effective producers of milk in the world. Nevertheless the genetic potential of New Zealand cows for milk production remains substantially underutilised. The present relatively low milksolids production per cow is a consequence of pasture-based feeding systems that do not provide all of the nutrients necessary for high (>30kg/cow/day) milk production. A potential means to increase per cow production is to balance pasture diets to provide the correct quantities and ratios of nutrients to meet target levels of milksolids production.

A review of the information available on the nutrient characteristics of feeds available in New Zealand for dairy cattle was completed. This indicated that most feed sources are documented only in very simple nutritional terms and generally few of the parameters necessary for ration balancing are included. Also regional and seasonal variation in feed quality is poorly defined. Implementation of ration balancing programs on dairy farms will require the development of a more comprehensive feed database, especially for forages.

The simulation model UDDER was used to investigate alternative strategies to profitably increase production per cow on a case study dairy farm. This analysis indicated that extending lactation by 30 days and supplementing pasture in early lactation with maize silage could increase milkfat yield by 17.9 kg per cow and the annual gross margin by $78.9 per cow. Thus there appears to be scope to profitably increase production per cow on the case study farm. However, UDDER is an energy-based model and does not consider the nutritional composition of the cows daily feed intake. CAMDAIRY, a computer program for analysing dairy cow rations, was therefore used to evaluate the nutritional adequacy of the diets "fed" to the cows by UDDER. This analysis suggested that the diets provided excess rumen undegradable protein (RDP) and as a consequence of this milk production was likely to be overestimated by UDDER. A diet that provided nutrients for higher levels of milk production was then formulated. The benefits of that diet were calculated using a spreadsheet partial budget that considers both immediate and carry-over effects of supplementation on financial returns. This showed that the diet formulated by CAMDAIRY could increase profit by $7.93 per cow.

It was concluded that ration balancing would be a useful aid to feed management on New Zealand dairy farms, but requires feed and animal monitoring systems to be put in place to determine the type(s) and period(s) of supplementation required. Ration balancing software such as CAMDAIRY should be used with caution until it has been more widely validated for New Zealand pastoral feeding systems. In particular this study suggests that further research on the utilisation of pasture protein is required.

Keywords: Milk production; UDDER; CAMDAIRY; supplements; ration balancing; pasture systems.

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Table of Contents

List of Tables

List of figures

Chapter 1

Introduction

Dairy farmers in New Zealand face some important farm management challenges in relation to herd productivity as the twenty first century is approached. One of these is to develop mechanisms to profitably exploit the genetic potential of New Zealand dairy cows which is presently poorly utilised for milk solids (Peterson 1988). This under utilisation of herd genetic capacity reflects current feeding systems which are mainly based on grazed pastures only or grazed pastures plus conserved derivatives such as hay and silage. Essentially, New Zealand's cows are unable to express their ability to produce milksolids, because pasture-only diets cannot fulfill the cow's diet requirements in terms of both quantity and quality during certain times of the year, especially when they are stocked at moderate to high rates.

The challenge to enhance the productivity of pasture-based dairy systems especially applies to the "top" farmers who have reached the point of "no where else to go" under present systems of management (Bryant 1990). These farmers are achieving per cow production of 300 kg MS per lactation and per hectare production of 950-1000 kg MS per year (LIC 1993) and are obtaining high (probably in the order of 75-85%) utilisation of annual pasture grown. They therefore have very limited capacity to grow and utilise more pasture (Bryant

1993). Thus, there is little scope for further improvements in production per cow and per hectare, through the manipulation of the key management variables in New Zealand dairy systems: stocking rate, calving date and grazing management.

Balanced against these challenges is an optimistic future for the New Zealand dairy industry. The recent agreement on trade and tariffs (GATT) should reduce both subsidies and the protectionist quotas of New Zealand's main competitors and markets respectively (NZDB 1994). Under the current situation New Zealand has achieved a 25% share of the world market for dairy products; it is thought that under the GATT agreement New Zealand dairy products will become even more competitively priced and attractive to buyers. Thus, it is expected in the medium-term that New Zealand farmers will benefit through higher milksolids payout. However, this will probably be mitigated to some extent by the strengthening value of the New Zealand dollar relative to the currencies of its major trading partners, increased competition from similar pasture-based producers in South America and Australia, and the adoption of lower cost systems of production in the U.S.A. mainly through economies of scale. Overall, however, the New Zealand dairy industry can look forward to a greater share in the international market and higher prices for dairy products.

1.1 Ration balancing

Given the outlook for the future of the New Zealand dairy industry and the need to improve on-farm productivity the following question can be posed. How can the intake and quality of a pasture diet be enhanced under grazing conditions in order to express more of the milksolids production potential of New Zealand dairy cows?

One possible strategy is to balance the cow's pasture diet to correct for nutrient deficiencies. The process of providing an animal with a balanced diet for energy, protein, carbohydrates, vitamins and minerals is called ration balancing (Edwards and Parker 1994). Ration balancing, which has been used extensively by farmers in the Northern Hemisphere under drylot conditions, should be evaluated in relation to New Zealand's pastoral dairy systems.

Pasture and drylot systems are very different; drylot farming offers a high degree of control over feed type and quality whereas pastoral farming is subject to variable pasture growth and quality and the animal can exercise greater diet selection under grazing conditions than with specially mixed rations. In addition other management and financial constraints are also present in the New Zealand dairy industry (Parker and Muller 1992).

As stated previously, ration balancing is most likely to be considered by farmers which are already achieving high production per cow with cows of high genetic merit, high pasture production (>18t DM/ha) and high (>80%) pasture utilisation. Farmers who have a lot of potential to further increase production from pasture, through improved management and more (or more effective use) of inputs, are likely to obtain greater financial rewards by initially exploiting these management alternatives (Parker and Edwards 1994).

There are several techniques for ration balancing. These range from simple calculations to latest computer software. Computer software will perform the necessary calculations to give a diet that will provide animals with the essential elements for a predetermined level of production at the minimum price possible (Varela-Alvarez 1988). Lean (1987) suggested that ration balancing should be seen as a means to provide a better diet, not necessarily the optimum diet (this is because the cost of feed still needs to be minimised). Nutrition programs provide the necessary means to abbreviate calculations in balancing diets. They also provide easy access to a feed database (Lean 1987).

1.2 Current New Zealand situation

The New Zealand dairy industry is very important to the nation's economy; it contributed around 15% of total export earnings in 1993. Although, in terms of world production New Zealand produces less than 1.5% of the world's milk, it is a key player in the international market of dairy products supplying approximately 25% of the total world trade (NZDB 1993). The industry has a vertically integrated structure which includes approximately 14,500 farms, 15 co-operatively owned companies and a unique marketing organization, the New Zealand Dairy Board. New Zealand has approximately 2.6 million cows each producing around 259 kg milksolids per lactation. The average farm area is 74 hectares and average herd size is 180 cows; these values have increased steadily over the past decade (LIC 1994).

New Zealand dairy farmers are world renown as "low cost" producers of milk. This is because feed, the major variable cost of milk production, is provided through grazed pasture. The principles of milk production in New Zealand are determined by the seasonality of pasture production, in which pasture growth is matched with animal requirements through the manipulation of stocking rate, calving date and drying-off date. Pasture utilisation is maximized through the manipulation of stocking rate and the timing of key physiological events (e.g. calving) so that changes in animal feed demand coincide with periods of pasture deficits and surpluses. Thus, cows calve in a concentrated period (typically eight weeks) during late winter-early spring. In spring, pasture quality and quantity are generally believed to be not limiting and can match the requirements of cows for an acceptable level of milk production (although well below genetic potential). In late spring-early summer pasture growth exceeds animal requirements and both pasture quality and milk production begin to decline. The typical lactation curve for a pasture-fed dairy cow therefore has a short (3-4 weeks) peak (i.e. poor persistency). In late summer-early autumn milk production reduces to 5-10 litres a day. Cows are dried off, normally in the latter half of the autumn, on the basis of pasture availability, condition score and other factors (Gray et al. 1992), Average lactation length for New Zealand herds has decreased from 237 to 221 days over the last 5 years (LIC 1994).

The relatively low productivity of New Zealand's high genetic quality cows under grazing conditions is a consequence of the feeding system. A variety of factors such as: cow management (short lactations, condition scores, size of replacements), pasture management factors (weeds, pests, pasture species, drainage, soil fertility) and climatic conditions (weather) all affect current milk production performance (Mackle and Bryant 1994).

1.3 Supplements

Traditionally, New Zealand dairy farmers have used supplements derived from pasture to overcome periods of pasture deficits. These deficits mainly occur in late summer and winter. Supplements commonly used are hay and silage made from pasture surplus to animal requirements in late spring-early summer. Brookes and Holmes (1988) calculated that on an annual basis 0-1.2 tonnes per hectare of supplements (crops, hay and silage) were fed to dairy cows on seasonal dairy farms in the Manawatu and South Auckland areas. Parker and Muller (1992) estimated that supplements (hay, silage) represented approximately 5% of the ration of New Zealand cows.

Generally, supplements in New Zealand are of low quality and do not meet the requirements of cows for high milksolids production. Many farmers regard supplement quality as being less important than supplement quantity, although, more recently there has been growing concern amongst dairy farmers and extension officers about the importance of maximising the quality of supplements fed to dairy cows (Dairy Exporter September 1994).

According to Lean (1987), there are several ways to increase the amount of feed for grazing dairy cows including: increasing pasture yields through fertiliser and irrigation; use of hay or silage and the use of grains or formulated rations. Obviously, the use of any type of supplement will depend greatly on the likely returns obtained from its use.

As the New Zealand dairy industry is based on a philosophy of low cost milk production in which grazed pasture provides the cheapest high quality feed to cows (Holmes 1994), the introduction of supplementary feeding other than hay or silage has been seen as a threat to the viability of dairy farms. Several authors (Meijs and Hoeckstra (1984); Rogers (1985) and Mayne (1990)) have identified substitution rate (the reduction in pasture intake per kg supplement DM consumed) as the main constraint to the profitable introduction of supplementary feeds to grazing systems. However, little research has been conducted to look at supplements in terms of metabolic energy (ME) value rather than DM, (Brookes

1993) in which case substitution rate would be less important (e.g. assuming that the energy value of the supplement is higher than pasture). Furthermore, New Zealand cows are underfed during some periods of the year especially in early lactation when animal requirements are high but intake is constrained by pasture availability. Under these conditions, substitution rate is likely to have little effect on the total productivity of the farm. In fact, substitution effects at this time of the year could be beneficial in terms of pasture productivity by helping to ensure that pastures are maintained in their most productive growth state.

1.4. Purpose and scope of the investigation.

The objectives of the present study are:

a. To investigate the potential of ration balancing in the context of the New Zealand pastoral dairy farms, particularly for situations where the potential for further increases in milk production are limited by the "traditional" all pasture management system.

b. To collate information on the nutritional characteristics of New Zealand feeds into a database for use in ration balancing programs.

c. To evaluate the effects of supplementing the diet of grazing dairy cows at critical times of the year on milk production per cow using the simulation model "UDDER" for a case study dairy farm.

d. To study available software on ration balancing and to perform runs with a ration balancing model (CAMDAIRY) to determine the suitability of diets fed to cows on the case study farm.

Alternative methods to improve per cow milk production of pasture-based dairy cows are presented in Chapter 2. In the following in Chapter information on the current nutritional characteristics of New Zealand feeds is discussed. The feasibility of some of these alternatives is evaluated in Chapters 4 and 5, respectively, using the dairy farm simulation model UDDER (Larcombe 1990a) and the ration balancing model CAMDAIRY (Irwin and Kellaway 1991). The concluding chapter includes comments on the models used and an overall discussion of the applicability of ration balancing to pasture-based dairy farm systems.

Chapter 2

Literature review

Several factors influence milk production from grazed pastures. Stocking rate, calving and drying-off dates, and grazing management are major determinants of milk production from New Zealand dairy farm systems. Stocking rate allows high pasture utilisation; calving and drying-off dates permit the matching of animal requirements with seasonal pasture production, and grazing management gives some manipulation of pasture growth to utilise feed surpluses and minimise feed deficits (Holmes 1993). However, under this system of milk production, the genetic potential of cows cannot be expressed and per cow production is often disappointingly low (Ulyatt and Waghorn 1993).

Options to improve production per cow while maintaining the advantages of a pasture-based system of production include; increasing pasture production through fertiliser inputs (Thomson et al. 1993), prolonging lactation length through the manipulation of calving and drying-off dates, and the use of strategic supplementation to overcome feed shortages and balance the cow's diet (Edwards and Parker 1994). These options are reviewed in this chapter.

2.1 Increasing pasture production

2.1.1 Nitrogen fertiliser

In New Zealand grass-clover swards are grazed by livestock throughout the year, and little fertilizer nitrogen (N) is applied; nitrogen fixation by clover provides the N supply, but growth of the most productive pastures can be restricted by N deficiency at some times (Ball et al. 1979). Leguminous herbage species provide the prime source of N in grassland systems where fertilizer N inputs are low.

The application of nitrogenous fertilizers to New Zealand pasture may produce responses ranging from 5 to 18 kg extra DM per kg N applied (Cameron 1993). Greater responses to N are obtained when it is applied in spring to rapidly growing pastures on farms with early calving, high stocking rates and high pasture utilisation (Bryant 1983; Thomson et al. 1991). In herds stocked at high rates and calved early, periods of pasture shortages often occur once winter-saved pasture has been grazed and spring pasture growth has not increased sufficiently to meet the increased demands of the herd (Bryant 1983). In these situations additional feed has to be obtained if milk yields are to be optimised and cow condition loss minimised in early lactation. Nitrogen fertiliser applications are a common method of increasing the amount of dry matter (DM) on the farm at this time of the year (O'Connor et al. 1989).

Pasture responses to N are linear at low rates of N application, before reaching a maximum yield and subsequently declining at higher rates of application (i.e. diminishing returns occur) (Morrison 1987) . Responses to N reflect growing conditions and are limited by temperature and radiation, especially in spring and autumn (Morrison 1987). At other times, moisture or leaf area index are the critical limiting factors to pasture growth. Nitrogen can be used to overcome periods of pasture deficits, but it will usually only increase available DM, rather than necessarily providing a better quality feed. Sometimes N applications may even decrease the nutritive value of the sward (Bryant 1983).

Several attempts have been made to define an economic optimum rate of N application but, since the value of pasture depends on its quality, utilisation and value of animal product, an optimum can only be defined for a specific system of management.

2.1.1.1 Animal response to N fertiliser

Animal response to N fertiliser can be measured in terms of milk production, liveweight gain and pasture saved. The response is strongly influenced by herbage utilisation, and hence by grazing pressure at individual grazings.

Holmes and Wheeler (1973) reported responses in kg milksolids (MS) per kg N applied of between 0.26 and 0.45 at low and high stocking rates, respectively. Bryant (1983) concluded that N fertiliser consistently increased milk production in early lactation and estimated the response to be 0.38 kg MS/kg N applied. Similarly, Thomson et al. (1991) found a response of 0.56 kg MS per kg N when urea was applied at 40 kg N/ha in July. An extra application of 60 kg N/ha two months later, resulted in a total response of 1.08 kg MS per kg N. The MS response to the latter application was achieved through the conservation of additional supplementary feed. The authors concluded that early calving with N applied in July could be used to overcome a pasture shortage in early lactation.

Likewise, the management system should maximise pasture growth and fully utilise the additional DM for MS production, rather than follow a less efficient route through conservation and supplementary feeding.

2.1.2 Phosphate fertilizer

In New Zealand the primary role of phosphate (P) is to encourage legume growth, which in turn stimulates N production and pasture growth (Aglink 1983). Increasing levels of available P therefore increases annual pasture production, but a diminishing response curve is evident as described previously for N inputs. Thomson et al. (1993) suggested that on farms with Olsen P values of less than 20, marked increases in dairy production would occur with increasing P fertilizer applications. For farms with Olsen P levels greater than 30, profitable increases in dairy production would only result if increased pasture production could be effectively utilised by an appropriate management change i.e. an increase in stocking rate. Thus, O'Connor et al. (1984) recommended that farms with Olsen P soil test values above 30 could possibly decrease or temporarily stop P applications, because they already have reserve P levels.

In terms of milk production, Thomson et al. (1993) reported that the response to P is strongly related to stocking rate. The authors reported a response rate of 4.2 kg MS/ha (Figure 2.1) for each unit increase in Olsen P ranging from 22-29 and 1.8 kg MS/ha when Olsen P levels are greater than 30.

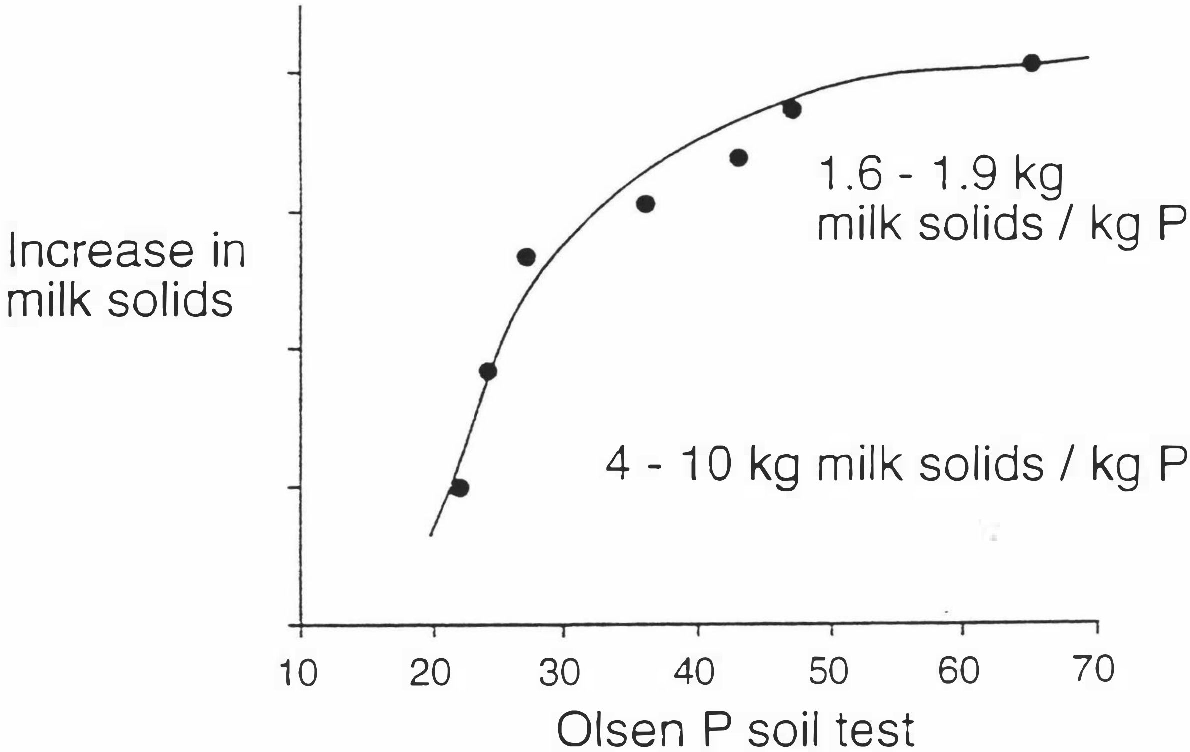

Figure 2.1. The relationship between Olsen P soil test and milksolids production (Thomson et al. 1993).

2.1.3 Potassium (K), Lime and Magnesium (Mg)

Potassium has an important role on high producing dairy farms, but unlike P, does not build-up reserves in the soil. This means that K applications should be based on soil test results to avoid excess uptake or underestimation of requirements that can limit pasture growth (O'Connor et al. 1984).

Thomson (1982) in a four year experiment found that lime significantly increased pasture growth over summer/autumn and produced corresponding increases in milk production. In the final year of the trial lime had little effect on pasture growth but a relatively large positive effect on milkfat. O'Connor et al. (1984) suggested that lime responses are very much related to soil pH. Thus, providing the pH is known the amount of extra pasture produced can be predicted and quantified. The optimum pH is 5.9; worthwhile responses above this value are unlikely. In addition to rising pH, lime also elevates Ca and Mg levels (Thomson 1982) and this may impact on milk production since both these elements are required by the lactating dairy cow (Wilson 1981).

The application of Mg in the form of MgO will increase soil, plant and animals levels (O'Connor et al. !987) . The amount of Mg applied should be based on soil test results for individual farms. Soil samples should be taken each 2-3 years (O'Connor 1984).

In general, fertiliser use will increase pasture DM production without altering the seasonal variation in production. The key factor in profitable fertiliser use (unless there is a specific deficiency) is that extra pasture DM grown is eaten by livestock. This usually means that a high stocking rate is desirable. If a farm has already a high stocking rate and pasture utilisation (>80% of pasture grown), the extra pasture grown could be used to improve animal intake. Despite this, high levels (> 350 kg MS/lactation) of production per cow are unlikely from the extra pasture eaten because pasture only diets cannot fulfill cow requirements for high levels of milk production (Muller 1993).

2.1.4 Irrigation

Irrigation provides another strategy to increase pasture production. Water applications during dry summers will usually result in a considerable increase in pasture growth; for example the application of 600 mm water resulted in an extra 3,200 kg DM/Ha being grown annually in two dry summers in the Manawatu (Holmes and MacMillan 1982). Water supply affects seasonal growth patterns as well as annual yields. There is no doubt that, on average, irrigation will reduce the seasonal variability in pasture growth and improve pasture quality during periods of moisture stress, but its economic feasibility is questionable in most localities (Leaver 1985a). The irrigation system should be able to supply 12-25 mm of water at each irrigation interval.

2.2 Calving and drying-off dates

2.2.1 Calving date and pattern

A seasonal calving pattern minimises milk production costs in New Zealand, because it allows the herd's feed requirements to be matched with the supply of grazeable pasture throughout the year. This is the main reason why 95% of New Zealand herds calve in the spring in a concentrated pattern (MacMillan et al. 1990). Calving is planned to commence in late winter, with a large proportion (approximately 75%) of cows entering the herd during the following 4 weeks and the remainder over the next 6-12 weeks (MacMillan 1984a). Thus, the concentrated seasonal calving pattern in New Zealand attempts to; maximize utilisation of pasture DM *in situ*, limit conservation of pasture as hay or silage, and minimise cropping and the use of high energy or protein supplements (MacMillan 1984a).

Calving date influences both the cow's level of feeding in early lactation and her lactation length (Holmes and Wilson 1987), and these two factors influence lactation yield. Lactation length is defined by calving date and drying-off date; while the level of feeding in early lactation is strongly associated with total milk yield per lactation (Bryant and Trigg 1982).

A herd's calving pattern primarily reflects the conception pattern during the previous seasons breeding programme (MacMillan 1984b). High submission rates and conception rates should reduce the final empty rate and the proportion of cows which may need to be induced (Hughes 1984). This will also increase the average number of days in milk for the herd, and concentrate labour requirements because rearing calves, oestrus detection, mating and calving will all occur over a relatively short time period (Holmes and Wilson 1987).

2.2.3 Drying-off dates

Drying-off date is an important element of pasture and animal management in New Zealand a dairy farm systems (Gray et al. 1992). Drying-off date must be set to achieve the following objectives; an adequate period of rest to allow the mammary tissues to prepare for the next lactation, an increase (or maintenance of) the amount of pasture on the farm and increase (or maintenance) of cow body condition score (Bryant 1984). Discontinuing milk allows the herd's feed requirements to be reduced suddenly and significantly. Prolonging lactation length will produce more milk in the present lactation but may prejudice the next lactation's production and increase feed costs (Holmes 1990; Gray et al. 1992). This effect can be profitably overcome by supplementing cows in late lactation (Holmes et al. 1994).

2.3. Supplements in dairy systems

The output of milk from pasture depends upon the combined effects of pasture grown and the efficiencies with which pasture is harvested and converted into milk by the grazing cow (Holmes 1990). High stocking rates and low daily herbage allowances, which are typically associated with efficient pasture utilisation, impose limitations on dairy cow performance from grazed herbage. Likewise, the seasonal pattern of pasture growth, and changes in pasture quality, also limit milk production from pasture. Supplementary feeding is therefore necessary at certain times of the year if consistent and high (> 30 litres day) levels of milk production from pasture are to be achieved (Leaver 1985a; Muller 1993). Supplementation of grazing animals is normally undertaken to; supply nutrients that are deficient in the cow's diet because of either low quality or quantity of the pasture available for grazing (Stockdale and Trigg 1989), increase total daily intake (Rogers 1985, Leaver 1985b, Grainger and Mathews 1989) or improve animal performance over that which can be produced from pasture alone (Mayne 1990). Likewise, Lean (1987) suggested that the provision of supplementary feed reduces the variation in annual income and may increase income levels, depending on the type, cost and effectiveness of the extra feed inputs.

The supplements provided to the animal may be classified into three general groups: (1) Energy supplements; (2) protein supplements; (3) inorganic nutrients (minerals and vitamins) (Allden 1981). In general, it is believed that energy supplements play the most important role under temperate pasture grazing conditions because a diet with adequate energy usually has acceptable levels of protein, minerals and vitamins. There are, however, some exceptions to this such as diets for animals in an active growing state or lactating cows with high genetic potential for milk production.

2.3.1 Effects of supplements on herbage intake

Including supplementary feeds (concentrates and forages) in the diet of grazing animals may increase total DM intake and organic matter digestibility but reduce the intake of pasture DM. This is called the substitution effect (Hodgson 1990). Substitution rate (decrease in pasture intake per kg supplement eaten) is mainly affected by the level of pasture on offer (Meijs and Hoekstra 1984) and the quantity and type of supplement provided (Rogers 1985).

Grainger and Matthews (1989) suggested a significant interaction between supplementation and pasture allowance for daily pasture intake. They observed a linear relationship between herbage allowance and substitution rate that was highly significant despite differences in pasture digestibility of 580 to 800 g/kg DM, pasture mass ranging from 2.3 to 5.5 t DM/ha and milk yields varying from 10 to 25 l/cow day. However, this relationship may not be present at pasture masses below 2000 kg DM/ha where intake is limited independent of pasture allowance (Holmes 1987). At high herbage allowances pasture substitution for supplement is high; this is mainly associated with a reduction in grazing time (Mayne 1990) rather than the rate of biting or bite size (Leaver 1985b). The effect of substitution rate on pasture intake can be seen in Figure 2.2. When pasture on offer is in the range of 6-12 kg DM/cow day, substitution rates for hay and silage are higher than for concentrates (Grainger 1991). As a result of substitution animals cannot maximise their intake of pasture when supplements are provided but if the quality of the supplement is higher than that of the pasture, total metabolizable energy intakes and the "balance" of the diet can be expected to improve. Thus, supplement type influences substitution rate; in the case of concentrates Rogers (1985) suggested a substitution rate effect of (65%) for energy supplements and (30%) for protein supplements. Substitution rate effects also may partly be related to the difference between the intake of nutrients from herbage and the cow's daily nutrient requirements. When this difference is negative (e.g. at a low herbage allowance) the substitution of herbage is low; when the balance is positive the substitution of herbage is high (Meijs and Hoekstra 1984). Other factors affecting substitution rate are pasture digestibility, season of the year and yield potential of the animal (Mayne 1990).

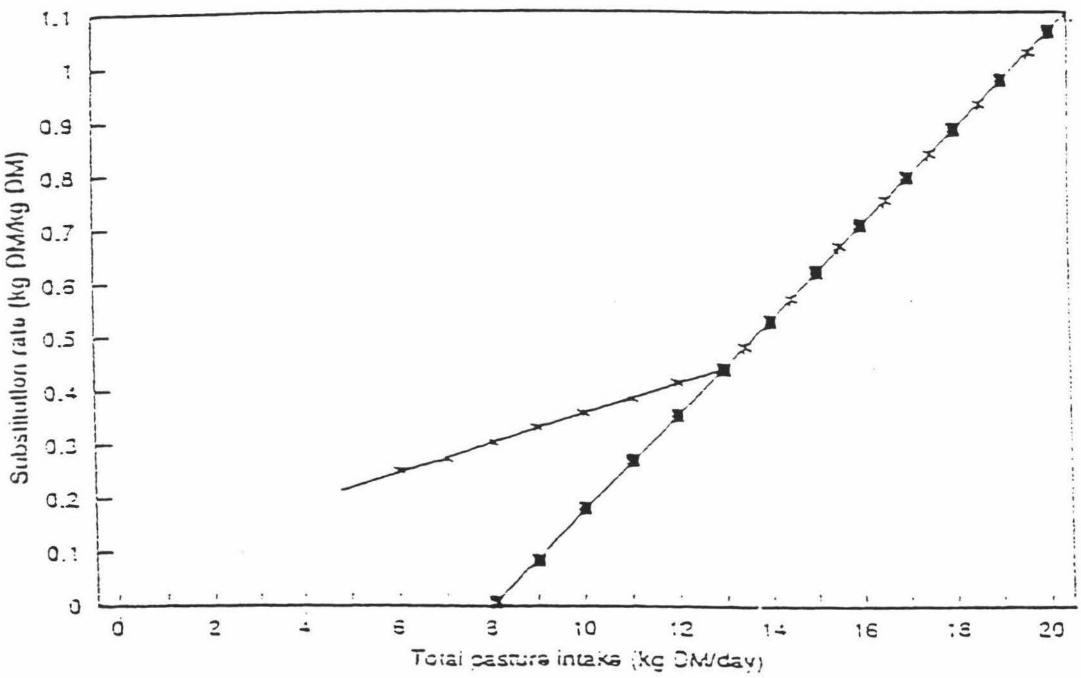

Figure 2.2. Pasture substitution rates at different pasture intakes when supplementing with concentrates (■) and fodder (*) (Grainger 1991).

In New Zealand low herbage allowances and high stocking rates are common, and under these conditions substitution rate would be of less importance if supplementation was implemented (Phillips 1994).

2.3.2 Dairy cow performance from concentrates

2.3.2.1 Milk response

A large number of factors affect the response of cows to supplementary feeding Figure 2.3. Each of the factors identified interact with each other and not only affect the immediate response to the supplement but also subsequent production. Predicting the result of supplementary feeding is therefore complex.

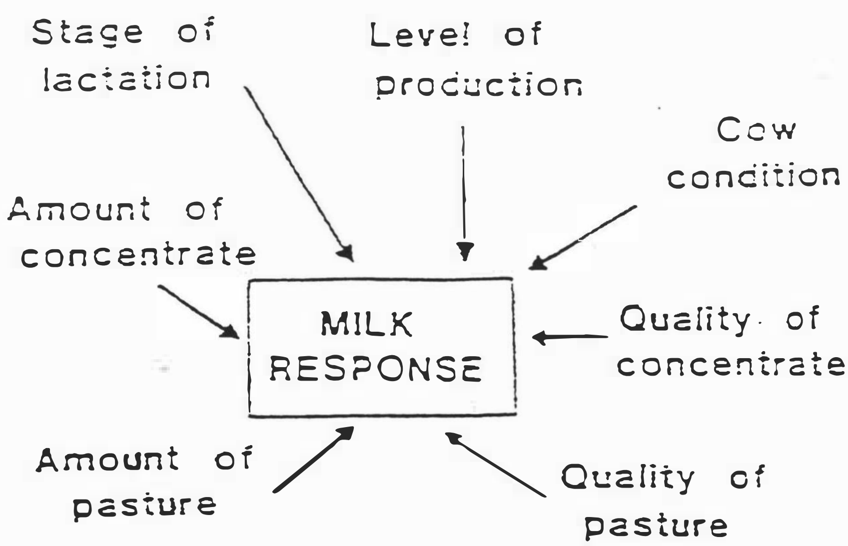

Figure 2.3. Factors affecting the response of cows to supplements (Rogers 1985).

Leaver (1985b) suggested that an improvement in the nutritional status of an animal through supplementation may lead to greater productivity during the feeding period (i.e. an "immediate response") or a change on production potential after supplementary feeding has ended (i.e. a "residual response" or carry-over effect). The carry-over effect can be represented through a continued increase in milk yield, an improved condition score or/and increase in average pasture cover (Kellaway and Porta 1993), or by changes in lactation associated with herd reproductive performance. Therefore, the cumulative carry-over effect of concentrates will almost always be greater than the immediate effect on milk production (Lean 1987).

The immediate response of grazing dairy cows to concentrates reported by different authors in different countries is summarized in Table 2.1. The responses are extremely variable, depending on the factors shown in Figure 2.3. For example, the response reported by Meijs (1985) was obtained with high fibre concentrates. The high responses obtained by Le Du and Newberry (1981) were obtained by supplementing grazing dairy cows for 4 weeks at a low herbage allowance. The same authors reported overall responses ranging from 2.9 to 3.5 kg milk/kg concentrates fed. The limited data from New Zealand is from experiments carried out in the late 50s, early 60s with cows of lower genetic merit (Bryant and Trigg 1982). The responses obtained by Taylor and Leaver (1984a) were with stall fed cows, and responses under grazing conditions could be expected to be different mainly because of diet selection.

Rogers (1985) reviewed the use of pasture and supplements for dairy cows in the temperate zones and calculated an average "immediate" response to concentrate supplements of 0.5 litres extra milk/kg concentrate eaten, the response ranged from 0 to 0.9 *l*/kg; the total response averaged 1.1 *l*/kg concentrate fed. While Lean (1987) suggested that the total milk response to concentrate feeding can be up to 1.2 kg milk/kg concentrate fed. Rogers et al. (1983) concluded that the economic value of the response depends very largely on the "carry-over" effect which is very variable.

Table 2.1. Immediate milk production responses to concentrate feeding of dairy cows in different countries.

Reference	Milk response	Units of response	Supplement type	Country
Meijs (1985)	1.3	kg milk/kg conc.	Concentrate	Holland
Gleeson (1981)	1-1.78	kg milk/kg conc.	Concentrate	Ireland
Le Du & Newberry (1981)	1-1.9	kg milk/kg conc.	Concentrate	UK
Taylor & Leaver (1984a)	0.5-1.6	kg milk/kg conc.	Concentrate	UK
Bryant & Trigg (1982)	-0.17-1.39	kg milk/kg DM	Various supp.	Australia/NZ
Rogers (1985)	0.0-0.9	kg milk/kg conc.	Concentrate	Australia

Stage of lactation has a major influence on the response of grazing dairy cows to high energy supplements. Cows tend to direct more energy towards milk production in early lactation, but in the last third of lactation a greater proportion of energy intake is directed towards body weight gain (Broster and Thomas 1981). This effect was confirmed by Stockdale et al. (1987) who found decreased milk responses to concentrate feeding as lactation progressed. Stockdale and Trigg (1989) also looked at interactions between stage of lactation and pasture allowance and found responses of 1.85, 0.053 and 0.059 kg milk, milkfat and milk protein, respectively, from feeding an additional kg DM to cows fed 6.8 kg DM of pasture per day in early lactation; the authors suggested that if the cows were fed 11.7 kg DM of pasture, marginal responses from concentrates would be more than halved.

Cow condition score affects the milk response to supplementary concentrates, particularly when supplementary feeding begins. Cows in low condition score in early lactation direct more energy to body weight than to milk production when supplemented (Grainger et al. 1982). Greater responses to supplementary feeding in early lactation can therefore be expected from cows at an optimum (> 4.5 units) condition score (Kellaway and Porta 1993). Because of this energy partitioning effect, Stockdale et al. (1990) showed that concentrate and pasture quality combine together and determine the magnitude of the milk response. In their experiments cows were fed high and low quality pasture supplemented with wheat and high energy pellets. The cows fed high quality pasture obtained similar milk responses for both supplements, while the response for cows fed low quality pasture favoured the high energy pellets. This was probably because the pellets provided a more balanced diet. Thus, balancing the diet of cows fed high quality pastures can be challenging; sometimes it requires the correction of deficiencies (fibre) (Kellaway and Porta 1993) or excesses (rumen degradable protein) (Muller 1993).

Cow genetic merit can influence the milk response to supplementary feeding. High breeding index cows direct more energy to milk production and lose more weight in early lactation than low breeding index cows (Wilson and Davey 1982). More efficient responses can therefore be expected in herds of high, rather than low, genetic merit.

The level of concentrate in the diet has significant implications on the milk response in grazing dairy cows. A progressive reduction in the response occurs as the level of energy increases in the diet because a greater proportion of energy is directed to body condition score rather than milk production. In addition, other nutrients can become deficient as the proportion of high energy supplement in the diet is increased (Kellaway and Porta 1993).

In summary, concentrates fed to grazing dairy cattle will increase the amount of milk yield, but the extent of this increase will depend on factors such as stage of lactation, level of pasture allowance and the herd's genetic potential (individual cow feeding is normally not an option under grazing conditions). In addition, other factors such as concentrate type may affect the herd's response to supplementary feeds. It is important to highlight that all of the factors discussed above interact with each other and the overall milk production response will reflect their combined effect.

2.3.2.2 Liveweight response

An increase in body condition score of lactating grazing dairy cows after being fed supplements is usually classified as a carry-over effect. The liveweight response to concentrate supplementation is highly dependant on cow condition at the time of supplementation. Cowan et al. (1977), working with four groups of Friesian cows grazing tropical pastures (*Panicum maximum*) fed 0, 2, 4 and 6 kg/cow day respectively of a maize soybean concentrate, found that concentrate feeding markedly affected the liveweight of cows at drying-off; cows being fed 4 or 6 kg/cow day were 50 kg/cow heavier on average than cows fed the lower rate. Similarly, Bryant and Trigg (1982) found that liveweight loss in cows in early lactation was reduced by 150 g per kg of supplement DM offered.

It can be concluded that when supplemented cows are achieving a high DM intake either reduced liveweight loss or increased liveweight gain can be expected. However, the extent of these changes will depend on factors such as cow condition score and stage of lactation (energy requirements), and the partitioning of nutrients towards milk production or liveweight gain.

2.3.3 Dairy cow performance from forages

Forages may be used to supplement grazing animals particularly when herbage is in short supply. They are usually less expensive than concentrates and can be used as a buffer to pasture (Leaver 1985a). The degree of benefit from forage supplementation will depend on the quality of the forage, the timing of feeding and the herbage allowance provided for grazing (Phillips and Leaver 1985a). Feeding conserved forage as a supplement to grazing cows when herbage quality is low or during feed shortages, generally results in increased total DM intake and improvements in animal performance (Phillips 1988).

2.3.3.1 Silage

Offering grass silage as a buffer feed when herbage allowance is restricted leads to increases in total DM intake (Phillips and Leaver 1985b). However, the voluntary intake of silage is normally lower than that of the fresh material from which it is made. The extent of this depression can be correlated with silage quality (Gordon 1989). Thus, when silage is of lower or similar quality to herbage, inclusion of silage in the diet generally results in a depression in milk yield relative to *ad libitum* herbage (Phillips 1988).

Feeding of medium quality silage (70% DM digestibility) to New Zealand cows in early lactation during 30 days had immediate effects on milk yield and milksolids production (Clark 1993). A total response of 26 g MS per kg DM silage was obtained in the experiment; the milk of cows fed silage had slightly lower milkfat (4.4%) and milk protein content (3.4%) than the control group. Phillips and Leaver (1985b) suggested that supplementation of herbage with silage increased rumination times, due to an increase in fibre intake. This resulted in lower milk yields but considerably higher milkfat content. Heifers in mid-lactation had higher intakes when silage was offered but the extra energy was partitioned towards liveweight gain in a study by Phillips and Leaver (1985b). However, milkfat yields were increased by offering silage, probably as a result of the extra energy and fibre intake.

The effects of inclusion of silage on the fat content of the milk are varied but tend to be inversely related to the effect on milk yield. Where silage is of better quality than herbage, fat content is decreased. Milk protein content tends to be reduced by including silage in the diet. This could arise from either a reduction in total energy intake or the low protein content and nitrogen retention of silage compared with fresh herbage or both (Phillips 1988, Gordon 1989).

Carry-over responses to pasture silage include increased average pasture cover and increased animal liveweight. In the long term silage may enable a higher stocking rate to be maintained (Phillips and Leaver 1985b). This was confirmed by Clark (1993), who found an increase in farm cover of 490 kg

DM/ha on the farmlet where cows had been supplemented with pasture compared with that of the control farmlet.

In summary, offering pasture silage to grazing dairy cows can result in different short term responses. The extent of these responses will mainly depend upon the quality of the silage on offer, but the interaction of other factors such as herbage allowance, cow genetic merit and stage of lactation will also affect the response obtained.

2.3.3.2 Maize silage

Inclusion of maize silage in the diet of grazing dairy cows can buffer variation in herbage intake and increase milk output per hectare (Phillips 1988). Usually, high quality maize silage has a high energy content and low crude protein, mineral and vitamin concentrations (see Table 3.2). It is also quite fermentable and has a relatively low DM cost (Lean 1987). These characteristics make maize silage a suitable supplement for dairy cows grazing high quality pastures (Satter et al. 1992). Supplementation of grazing dairy cows with maize silage at up to 33% of the diet generally increases total DM intake (Hutton and Douglas 1975), although substitution rates can be high, ranging from 0.47 to 1.40 (kg pasture DM per kg silage DM) depending mainly on herbage allowance (Phillips 1988).

The average milk production response to maize silage supplementation of pastures is 0.9 litres of milk per kg DM of maize silage eaten (Stockdale 1991). However, milk production responses to maize silage are variable. Generally, they are positive when maize silage is fed at low herbage allowances (Hutton and

Douglas 1975) or when maize silage is supplemented with rumen undegradable protein (e.g. meat meal) (Davison et al. 1982). Recently, Moran and Stockdale (1992) found positive, but not significant, milk and animal intake responses when cows grazing perennial pastures were supplemented with maize silage in early lactation.

Leaver (1985a) suggested that if maize silage is offered *ad libitum* it may be eaten in preference to grazed herbage. However offering maize silage for short periods once or twice daily may lead to increases in milk yield and liveweight gain (Mayne 1990).

In summary, maize silage appears to have potential for much greater use as a supplement for grazing dairy cows under New Zealand conditions. High energy maize silage may promote utilisation of pasture protein by encouraging microbial growth and hence increase the amount of amino acids reaching the small intestine (Satter et al. 1992), and improve rumen efficiency. In other words supplementing ryegrass-clover pastures with maize silage should help to provide a more balanced diet for pasture-fed dairy cows.

2.3.3.4 Hay

Animal response to hay supplementation is strongly influenced by its quality. In New Zealand hays are generally of low quality (See Table 3.3). Rogers (1985) reported that hay fed as a supplement to restricted pasture in early lactation gave 9 g. milkfat directly and 23 g. milkfat over the whole lactation per kg of hay fed. Generally, cows could not consume sufficient hay to meet energy requirements due to its low digestibility limiting intake and digestion. When herbage allowance is restricted, offering hay increases the yields of milk, fat, protein and lactose, but milkfat content may be depressed (Leaver 1985a).

Hay is used mainly in New Zealand to maintain cow condition prior to calving while pasture is saved for early lactation (Holmes and Wilson 1987), although, some farmers also feed hay in early lactation to provide fibre to cows fed on lush leafy spring pasture. This practice was supported by Leaver (1985b), who suggested that hay can be used to increase the fibre intake of grazing dairy cows in spring but intakes are low unless access to herbage is limited either in quantity or by time.

2.3.4 Supplementary feeding and reproduction

Cow condition at calving and the level of feeding after calving both significantly effect the post-partum anoestrum interval (Rogers 1985). Moreover, condition score at mating, which is mainly affected by condition score at calving and feeding level between calving and mating, is closely related to conception rate (Haresign 1979). Post-partum nutrition has little effect on the reproductive activity of cows in good condition at calving, but a marked influence on oestrus 90 days post-partum in cows poorly fed prior to calving (Haresign 1979). The energy balance of the cows around the time of mating may also have a significant effect on conception rate; cows which are losing weight at the time of mating are less likely to conceive than those gaining weight (Butler and Smith 1987).

When pasture is limiting, the requirement for supplementary feeding will be considerably reduced if cows are at an appropriate condition score at calving (Rogers 1985). In New Zealand, McDougall (1993) concluded that low condition score at calving and at the start of mating was associated with anoestrus and estimated that for each unit decrease in condition score at calving the interval from calving to first oestrus increased by about 8 days. Loss of one condition score after calving only increased the interval from calving to first oestrus by about four days. Thus, condition score at calving appears to be more important than the maintenance of condition score after calving.

Taylor and Leaver (1984b), working with cows fed high and low quality silage, found that calving intervals for the cows fed with high quality silage were significantly lower than those offered low quality silage. The authors attributed this effect to poor conception rates since days to first service were similar for both treatments.

Conception rate and reproductive efficiency are reduced as a result of high crude protein intake (Elrod and Butler 1993). High crude protein intake results in elevated levels of urea in the blood, milk and tissue fluids which include uterine secretions and vaginal mucus. These secretions may reduce sperm viability and reduced embryo survival. Hence, high intake of degradable protein supplements (e.g. soya bean meal) could adversely affect the reproductive performance of dairy cows, especially if they are already grazing high quality pastures (Williamson and Fernandez-Baca 1992). In New Zealand, this effect was confirmed by Moller et al. (1993) who found high blood urea levels in herds with an anoestrus problem, especially around the time of mating. Similarly, Elrod and Butler (1993) found reduced conception rates in heifers fed high degradable protein diets.

There are consistent reports of an association between increased bodyweight loss and reduced fertility (Lean 1991). From a review of trials, he estimated that for each 0.1 kg of bodyweight gain per day, which a cow achieved above average, calving to conception interval was reduced by 21 days. Workers in USA, Australia and the UK have found very significant reproductive responses to increased body score at calving time. The responses to increased body condition score have not yet been fully defined but will probably be curvilinear with diminishing returns above a condition score of 6 units (Lean 1991). Generally, this situation is unlikely to happen under grazing conditions.

Feeding the grazing dairy cow during the dry period to gain weight is a practice that can be worthwhile and in some circumstances the supplementary feeding of dry stock may be warranted because cow condition score at calving can determine productive and reproductive performance after calving (Grainger and McGowan 1982).

The preceding discussion indicates that the reproductive performance of the dairy cow is influenced by a very large number of interacting factors. These include animal, human or management, and environmental factors. In relation to the animal, factors such as hormonal and health status, metabolic, mineral and condition score are of importance. The role of supplements in the improvement of the reproductive performance of grazing dairy cows is mainly related to decreased liveweight loss in early lactation. They may also decrease the amount of RDP in the diet and help to improve overall herd reproductive performance.

2.4 Ration balancing

Ration balancing is the process of formulating animal diets to provide an adequate quantity of energy, protein, minerals and vitamins to achieve a desired level of production (Muller 1993b). Ration balancing involves both the determination of an optimum diet for a particular situation and the evaluation of the nutrient composition of available feeds (Owen 1983). A ration balancing program should therefore include information on the nutritional requirements of the animal and expected DM intake (VandeHaar and Black 1991) and the nutritive value and costs of available feeds (Varela-Alvarez 1988).

Ration balancing programmes calculate the animal requirements based on the information provided by the user. This information generally includes average milk production, lactation stage, average dry matter intake, average age of the cows (lactation number), average body weight, average condition score and average peak milk yield (VandeHaar and Black 1991; Muller 1992). Of these variables average DM intake is the most difficult factor to estimate under grazing conditions because of the variation in pasture quality and cow selection (Muller 1993a; Edwards et al. 1994). The correct estimation of total ration and pasture DM intake is one of the key issues in balancing the diet of cows grazing pastures (Muller and Holden 1994). In a recent study Hoffman et al. (1993) concluded that any ration balancing program of grazing dairy cows should include the regular monitoring of pasture quality to allow reformulation of the diet according to pasture characteristics. In their experiment this option resulted in the most profitable supplementation option.

2.4.1 Nutritional requirements of grazing cows

In New Zealand the nutritional requirements of dairy cows, and the feeds that they could potentially consume, are based on the metabolizable energy system (ARC 1980). Under this system animal requirements are expressed in terms of energy, protein, minerals and vitamins. Animal energy requirements are divided into production (pregnancy, milk production and liveweight gain) and maintenance (Geenty and Rattray 1987). Energy requirements for the maintenance of grazing animals can vary widely with animal size, age, quality of diet, availability of pasture, terrain, climate, physiological state of the animal and muscular activity. Grazing activity increases the maintenance requirements of dairy cows relative to those under confined feeding conditions (Table 2.2).

Table 2.2 Energy (E) costs of physical activities per kilogram of liveweight (LW) of dairy cows. (Source: CSIRO 1990).

ACTIVITY	E cost /kg LW
Standing (compared with lying)	10 kj/d
Changing body position (Standing and lying)	0.26 kj
Walking (Horizontal component)	2.6 kj/km
Walking (Vertical component)	28 kj/km
Eating (Prehension and chewing)	2.5 kj/h
Ruminating	2.0 kj/k

Energy requirements for liveweight gain are mainly influenced by the nature of the gain, but factors like sex, age and physiological state are also important (ARC 1980). While those for pregnancy depend mainly upon the energy contained in the growing foetus and increase exponentially during the last third of pregnancy (McDonald et al. 1988).

Milk is produced from energy obtained either directly from the feed or indirectly by the mobilisation of body reserves. The energy required for milk synthesis is mainly influenced by milk composition and varies within and between breeds (Holmes and Wilson 1987). Under grazing conditions cow energy intake limits milk production (Kellaway 1992). Alternative feeding practices to overcome this deficiency and balance the diet of grazing dairy cows include supplementary feeding of cereal grains (Kellaway 1992; Muller 1993b), including those containing additional long chain fatty acids (King et al. 1990), or feeding high quality maize silage (Satter et al. 1992).

The protein requirements of grazing animals are more complex than for energy. Fresh forages contain high quantities of crude protein (CP) and about 70% of this is broken down by micro-organisms in the rumen (i.e. (RDP) rumen degradable protein). The balance escapes (i.e. escape, by-pass or (UDP) undegradable protein) to the small intestine, for digestion and absorption. Rumen micro-organisms are capable of synthesizing all the essential amino acids either from plant protein or non-protein nitrogen (Leng and Nolan 1984). The supply of amino acids to the small intestine comes from UDP and the microbial protein synthesized from RDP. The amount of microbial protein depends greatly on the energy available and on the supply of minerals, especially sulphur (Waghorn and Barry 1987). ARC (1980) assume that for each MJ of dietary ME consumed the maximum amount of RDP that can be incorporated into microbial protein is 8.4 g. The UDP requirements of tissue represent the difference between the net tissue protein requirements (Ptissue) and that supplied from microbial protein (RDPtissue). In this sense, the total protein requirements (Total P) are RDPreq + UDPreq. CAMDAIRY uses a modification of ARC (1980) to calculate the protein requirements of cows (Hulme et al. 1986). The high CP content of ryegrass-clover pastures (Table 3.1) and its high degradability may limit the amount of UDP reaching the small intestine (Satter et al. 1992). The inclusion of small amounts of UDP in the diet of grazing dairy cows may provide an improved amino acid profile reaching the small intestine and hence improve milk production per cow

(Muller 1993b). The inclusion of low levels of fish meal (0.8 kg) in the supplement of cows fed high quality pasture silage produced large milk responses at low (0.8 kg supplement per cow day) and medium (4 kg supplement per cow day) levels of supplementation (Gordon and Small 1990). Finally, Mayne (1993) concluded that the milk production response to the inclusion of UDP in the supplements of lactating dairy cows fed pasture silage is mainly affected by level and type of the protein supplement and by variations in silage quality.

Minerals are essential for maintaining an adequate state of production. Minerals are divided into macrominerals and trace minerals depending in the amount required in the diet (Church and Pond 1988). High producing dairy cows usually require supplementation with calcium and phosphorus, because they have a large concentration of these elements in milk (ARC 1980). The mineral status of dairy feeds should be monitored to avoid mineral deficiencies that can limit high levels of production. In CAMDAIRY constraints can be set for calcium and phosphorus in the diet to achieve target levels of production. If the mineral content of the planned diet is less than the recommended level a mineral premix (or other appropriate mineral source) can be included to overcome the deficiency.

Vitamins are required to perform specific metabolic functions. Water soluble vitamins (B, C) requirements are met by rumen micro-organisms (Church and Pond 1988). Fat soluble vitamins (A, D, E) requirements must be met by the diet. Usually, mineral premix is formulated with vitamins to overcome possible deficiencies.

2.4.2 Methods for ration balancing.

Ration balancing methods range from simple basic calculations (Pearson's square, simultaneous equations) to advanced computer software (Varela-Alvarez 1988). In the case of modern computer software, like "CAMDAIRY", the calculations are performed using a linear programming (LP) algorithm. The use of LP allows diets to be formulated relative to objectives, least cost formulation and maximum profit, and subject to specific nutritional requirements for target levels of production.

The least cost option results in the formulation of a diet from specific feed sources that fulfils energy, protein and mineral requirements at a minimum cost (Hulme et al. 1986). As feed (direct and indirect) is usually the largest production cost (50-60%), the least cost option is mainly used by feed manufacturers to ensure that nutrient requirements are provided at the minimum cost (Lean 1987).

The maximum profit formulation option aims to maximize income (Varela-Alvarez 1988). This method considers feeds cost as an expense and milk production as income. The LP is used to maximize income while satisfying animal requirements. It is essential to know maximum dry matter intake, feed costs, feed composition and the milk production response to nutrients for models of this type.

A more recent approach to ration balancing (Lara 1993) uses multiple objective fractional programming to include several objective functions. The advantage of this approach over traditional least cost formulation is that it allows the introduction of a second objective (i.e. maximisation of the inclusion of specific feeds) which permits a diet that fulfils all the requirements for a specific level of production.

2.5 Summary

A number of options are available to increase per cow performance from grazing systems. Nitrogen fertiliser can provide a rapid method to improve overall animal DM intake, but it does not necessarily enhance pasture quality and responses are subject to environmental conditions at and following applications. The use of fertilisers such as phosphate, lime or potassium provide a long term investment in the overall fertility of the soils and therefore result in increased annual pasture production. However, pasture growth responses under this strategy take time and do not mitigate the inherent limitations of pasture quality (although changes in sward composition induced by improved soil fertility may increase the nutritive value of pasture).

The time of calving and drying-off date is an important determinant of production per cow, because in a pasture-based system, it directly affects early lactation feeding and lactation length. Extending lactation length normally results in higher milk production at the expense of condition score and average pasture cover. Management strategies must be developed to overcome this. This is discussed more fully in Chapter 4.

Supplementary feeding of grazing dairy cows may overcome the nutritional deficiencies of pastures and improve their reproductive performance. However, animal responses to supplementary feeding are influenced by a range of factors such as supplement type, supplement quality, stage of lactation, cow condition and pasture quality. In addition, cows may substitute supplements for pasture and this effect can decrease the economic response to supplements.

Ration balancing provides an opportunity to improve the quantity and quality of the diet of grazing dairy cows. However, the implementation of ration balancing for grazing dairy cows is presently limited by factors such as the estimation of cow's intake and determination of pasture quality. In the next Chapter feed quality data, including that for pasture, are presented.

Chapter 3

New Zealand feeds

In pasture-only dairy systems, such as those which predominate in New Zealand, grazed pastures must supply the animal's requirements for maintenance, milk production and pregnancy. Cows graze pastures all year round and hence their ability to express their genetic potential will reflect both the quality of pasture on offer and the grazing management system used. However, it is known that pastures cannot fulfill the cow's requirements for high (>30kg/day) milk production (Ulyatt and Waghorn 1993). Furthermore, the nutrients available to the animal from pastures are more variable than those provided through a drylot system where feed types can be adjusted to ensure a uniform diet through time.

The aim of this chapter is to present an overview of the quality parameters of feeds available in New Zealand and to identify the nutritional information of pastures and feeds required for ration balancing.

3.1 Pastures

Forages such as pastures are an essential part in ruminant feeding and in achieving a balanced ration (Muller 1993a). Although pastures are the main source of feed supply for dairy cows in New Zealand, published information regarding their nutritional value is scarce (Edwards and Parker 1994). This also applies to other potential sources of dairy feeds. Where information is available on pasture quality the data usually covers only a limited range of parameters such as DM, digestibility, crude protein, metabolizable energy and some minerals. In many cases only the first two factors have been measured. This lack of information can partially be attributed to the fact that in grazing situations, pasture quality determinations are complicated because pasture is a highly variable feed source and can even change on a daily basis (Wilson and Moller 1993).

3.1.1 Nutritive value of pasture.

The feeding value of pasture under grazing conditions has primarily been considered as the potential of herbage to supply energy to the animal, although under certain conditions other nutrients including protein, minerals and vitamins may be limiting. Nutritive value is the concentration of nutrients in a feed and is dependent on the digestibility of the feed and the efficiency with which the digested nutrients are converted to animal products (Ulyatt 1981). Paterson et al. (1994) suggested that the two main factors determining forage quality are forage intake and digestibility. Ultimately, the performance of the animal is the true indicator of forage quality.

Maturation affects the nutritive value of pasture. Several changes occur during the process of plant maturation; structural carbohydrates and lignin increase rapidly in stem and leaves (Van Soest 1982), and there is a concurrent decrease in protein nitrogen and digestibility (Waghorn and Barry 1987). There is an associated reduction in digestibility and intake with these changes (Minson 1982). However, Holmes (1987) stated that pasture digestibility does not affect DM intake consistently when pasture allowance is restricted but it does affect metabolizable energy intake. A high percentage of fibre (ADF, NDF) in the diet decreases voluntary feed intake and digestibility (Linn and Martin 1991). This means that the intake of pasture will usually decrease during summer and autumn; this factor contributes to the steeper decline in the New Zealand milk yield curve compared with that of US drylot feed cows (Edwards and Parker 1994).

Environmental factors affecting the nutritive value of forages are: temperature, solar radiation, water stress and nutrient deficiencies (Linn and Martin 1991; Buxton and Fales 1994). These environmental factors impact on plant maturity and hence forage quality and determine the degree of variation in forage quality throughout the year (Buxton and Fales 1994).

The changes in pasture DM digestibility demonstrate a seasonal trend. Thus, pastures in New Zealand have a high digestibility in winter and spring; and this falls in summer and increases again in autumn (Bryant and Trigg 1982).

In summary, while many factors affect the nutritional characteristics of pastures, the two main sources of variation are environmental and plant factors. Environmental factors are difficult to control, but plant factors can be mitigated through grazing management.

3.1.2 New Zealand pastures

Information on the nutritional characteristics of pastures in New Zealand is limited (Table 3.1). Most of the pasture data shown in Table 3.1 were derived by proximate analysis in which the organic components are expressed as a proportion of the dry matter (DM) to allow comparisons between feeds. Crude protein is calculated by multiplying the total nitrogen concentration of the plant by 6.25 (Kjeldahl method). A common feature among the species reported in Table 3.1 is that there is a lack of detail on nutritive parameters of pastures which are important in dairy cattle nutrition. Dry matter, CP and energy are of vital importance in animal nutrition but they do not adequately describe the potential of various pastures for achieving high levels of animal production. Also, it is important to highlight the variability in DM, CP, DMD and ME presented in similar species throughout the year, especially between seasons. Data on seasonal variation in pasture nutritive value is shown in Table 3.1. For example, the effect of pasture maturity can be seen on the concentration of CP, as maturity increases, CP decreases. The CP concentration of pastures usually varies from levels of 5% of the DM for browntop (*Agrostis tenuis*) summer pasture to 28% approximately for white clover (*Trifolium repens*). The DM percentage for ryegrass-clover swards varies dramatically between seasons from 15% in spring to 30% in summer. A similar variation can be seen in other nutritional parameters such as digestibility, ME content and minerals. The highest ME content (12.2 MJ/kgDM) is reported for white clover. Other forages with ME content over 12 MJ/kgDM are ryegrass-clover mixtures of spring immature pastures and Tama ryegrass.

Table 3.1. Nutritional parameters of New Zealand pastures. (Sources: Bryant et al[1]. (1983); Holmes and Wilson[2] (1987); Ulyatt et al[3]. (1991); Ulyatt[4] et al. (1980); Lancashire and Ulyatt[5] (1974); Rattray and Joyce[6] (1974); Ulyatt[7] (1981); John and Lancashire[8] (1981)).

Pasture Type	Sou[a]	DM[b] %	DMD[c] %	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
				------------gr per kg DM--------------					
Ryegrass/clover									
Ry 70%-Cl30%	1	15	74	188		7.6	3.2	2.2	2.2
Pressed pasture	1	19	71	161		6.8	2.8	1.8	1.6
Spring leafy	2	14	75	240	11.8	6.0	4.5	1.5	1.5
Spring good quality	3		78	253	11.2	4.5	3	2	1.2
Spring short	4	15		220	12.0				
Spring mixed	4	15		200	11.2				
Spring rank	4	18		150	10.3				
Summer,leafy	2	20		150	10.0	8.5	4.0	2.0	2.0
Summer,leafy	4	18		150	10.3				
Summer dry,stalky	4	30	65	100	8.0				
Summer good quality	3		67	148	10.3	4.5	3	2	1.2
Autumn	4	15		250	10.8				
Autumn good quality	3		72	255	10.8	4.5	3	2	1.2
Winter,autumn saved	2	17		200	10.0	7.0	4.0	1.8	1.5
Winter leafy	2	14		260	11.2	7.0	4.5	1.5	1.5
Winter short	4	15		250	11.2				
Winter good quality	3		79	253	11.2	4.5	3	2	1.2
Kikuyu grass,summer	2	22		140	8.5	6.0	3.9	1.8	0.6
Browntop dominant									
Autumn,leafy	4	15		200	10.8				
Winter	4	15		220	11.0				
Spring	4,5	15	82	220	11.5				
Early summer	4	20		170	9.0				
Mid summer	4	50		50	7.0				
Spring	5		82	221					

Pasture Type	Sou[a]	DM[b] %	DMD[c] %	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
				------------gr per kg DM-------------					
Perennial Ryegrass	6			205	11.7				
Primary growth ryeg	7		83	211					
Trimmed ryegrass	7		80	148					
Regrowth ryegrass	7		81	139					
Paspalum,leafy	2	18		180	10.5	7.5	4.0	2.5	0.6
Paspalum flowering	2	23		100	9.3	5.6	3.0	2.5	0.4
Red clover,spring	2	17		280	11.5	11	3.5	3.0	0.8
Red clover pre-bloom	4	18		230	11.0				
Redclover full-bloom	4	25		180	10.0				
Tama,ryegrass	2	12		240	12.0	4.0	4.0	1.5	2.5
Tama ryegrass leafy	4	15		240	12.0				
Paroa ryegrass	4	15		230	11.0				
Maku lotus	8			267					
Lotus corn"empire'	8		71	218					
Lotus corn"maitland"	8		70	205					
Fakir saifoin	8		78	213					
White clover	6			258	12.0				
White clover mature	7		74	236					
Whiteclover regrowth	7		80	271					
White clover	2	15		280	12.2	12	4.0	3.0	3.0

a = Source, b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega Joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.2 Silage

Silage is produced through the controlled fermentation of forages. High quality-high intake silage is the product of high digestibility at harvesting and appropriate fermentation in the silo (Gordon 1989). Thomas and Thomas (1989) recognised maturity of the crop at cutting as the most important factor determining the nutritive value of silage because it will determine silage digestibility which is almost always lower than that of fresh pasture because of the loss of water soluble carbohydrates during fermentation (Holmes and Wilson 1987). Other factors affecting silage quality are: chop length, wilting, additives and anaerobic storage (Gordon 1989). Silage is a preferred form of conservation over hay because it requires a shorter period of herbage accumulation, provides resistance to unfavourable climatic conditions and often has higher digestibility (Hodgson 1990). Silage quality is very variable, it ranges from a product unable to support maintenance requirements to a high quality forage providing the major part of a ration supporting high levels of production (Rogers 1985). However, animal intake and nutritive value per unit of DM is usually low ranging from 10.5 MJME/kgDM for maize silage to less than 8 MJME/kgDM for poor quality pasture silage (Frame 1991). In New Zealand silage is made during periods of pasture surplus to be fed during periods of pasture shortage. This system of silage making has contributed to farmers producing large quantities of silage of medium to poor quality (Table 3.2), because pastures are usually mature and stemmy at the time of harvest. Table 3.2 shows that pasture silage DM content varies from 28 to 20%, digestibilities range from 70% for kiwifruit silage to 55% for poor quality pasture silage. Additive use (e.g. formaldehyde and formic acid) may increase digestibility values by 1-2 points compared with high quality pasture silage. Kiwifruit silage shows a great potential as a supplementary feed for grazing dairy cows because it has a low crude protein content and high ME (11.5 MJ/kg DM).

Table 3.2. Nutritional parameters of New Zealand silages. (Sources: Holmes and Wilson[1] (1987); Barry[2] (1975); Ulyatt et al[3]. (1980); Farm Facts[4] (1993); Bramwell et al[5]. (1993); Parker W.J[6] (1994) *pers.comm;* Densley R.J[7]. (1994) *pers.comm*).

Silage type	Sou[a]	DM[b]	DMD[c]	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
		%	%	--------Grams per kg DM.------					
Grass/clover mix									
Good quality	1	23	60	200	10.0	7.0	4.3	1.7	1.7
Poor quality	1	28	50	150	8.0	5.5	2.8	1.4	1.6
Pasture silage	2	20	64	151	9.7				
P+formaldehyde	2	22	63	148	10.2				
P+formaldehyde+formic	2	20	62	140	9.2				
Lucerne	1	20		200	9.5	10.0	2.6	2.0	0.5
Lucerne high moisture	3	23		160	10.5				
Maize,early dent	1	30	65	80	10.3	3.0	2.0	1.2	0.1
Maize,mature	3	35		80	10.5				
Maize silage	7	34	67	68	10.4				
Maize silage	7	36		68	11.5				
Maize silage	7	34	66	71	10.3				
Maize silage	7	31	70	71	10.9				
Maize silage	7	32	64	66	10.0				
Maize silage	7	34	66	71	10.3				
Kiwifruit wholefruit	4	14		90	11.5				
Kiwifruit skin&seeds	4	38		110	8.0				
Kiwifruit silage	5	16		170					
Kiwifruit silage	6	86	70	102					
Kiwifruit/grass	6	91	58	151					

a = Source , b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.3 Hays

Hay is produced by conserving forages through drying. Hay quality is highly dependant on the quality of the standing forage at the time of harvesting. Other important factors in determining hay quality are nutrient losses during drying and harvesting (respiration loss), and hay losses during storing (Rotz and Muck 1994).

As with any other forage, hay quality depends on the amount consumed by animals and its digestibility. Rogers (1985) pointed out that in high rainfall areas hay cannot satisfactorily be cured until late spring-early summer when crops are generally mature: digestibilities range from 50-63% with ME concentrations of 6.7-9.0 MJME/kgDM. In this sense, the nutritional effectiveness of hay is limited by its digestibility. Hay quality is therefore of vital importance if high levels of animal performance are to be achieved.

Hay digestibility is generally 5% to 15% lower than that of the forage from which is made (Holmes and Wilson 1987). In New Zealand hays are generally harvested in December and January when pastures are maturing and developing seed heads. Hay quality is therefore generally medium to poor, and could be improved through earlier harvesting (November). This would result in lower yields at harvest and higher costs per kgDM, but this ignores the nutritive value of the hay and on an energy protein, or animal production potential basis, for example, costs could be lower overall for harvesting strategies that produce high quality hays.

The summary for New Zealand hays (Table 3.3) shows that they have a DM content of 85%, digestibility of 54-62%, ME concentrations of 7.0-9.7 MJME/kgDM and CP of 170-80 g/kgDM. Generally, lucerne hays are of greater quality, with digestibility ranging from 66-55%, ME concentration from 10.5-8 MJME/kgDM and CP content ranging from 200-120 g/kgDM.

Table 3.3 Nutritional parameters of New Zealand hays. (Sources: Holmes and Wilson[1] (1987); Barry[2] (1975); Ulyatt et al[3]. (1980)).

Hay type	Sou[a]	DM[b] %	DMD[c] %	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
				--------Grams per kg DM---------					
Grass-clover mix									
Good quality	1	85	60	170	9.7	8.0	4.0	2.0	2.0
Medium quality	1	85	57	110	8.5	6.0	3.5	1.9	1.7
Poor quality	1	85	50	70	7.3	4.0	3.0	1.8	1.5
Hay early 1Nov	2		62	122	9.0				
Hay late 1Dec	2		54	100	7.8				
Lucerne pre-bloom	1,3	85	67	200	10.5				
Lucerne early-bloom	1,3	85	65	180	9.8				
Lucerne mid-bloom	1,3	85	60	170	9.0				
Lucerne full-bloom	1,3	85	55	150	8.5				
Lucerne weathered	1,3	85	55	120	8.0				
Red clover	3	85		150	8.5				
Oat milky ripe	3	85		60	8.0				
Meadow Hay									
Young leafy	3	85		120	9.0				
Mature	3	85		100	8.0				
Weathered	3	85		80	7.0				

a = Source, b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.4 Straws

Straws are the dried stems and leaves of forages after the removal of seeds. They may be conserved following threshing of grass for seed or cereal crops. In general, straws are characterised by low nitrogen content, low digestibility, low mineral content and a low rate of rumen outflow (Preston and Leng 1987 and Table 3.3). These characteristics do not allow a high DM intake (Brookes et al. 1992) and hence decrease the potential feeding value of straws.

Straw quality can be improved by physical, chemical and microbiological methods. However, straws are often considered to be of such low feeding value that they are burned or cultivated back into the soil in countries with specialised livestock production systems. In New Zealand straws are rarely fed to cattle because of their low feeding value (Table 3.4). On average they have a DM content of 85%, digestibility ranges from 40 to 50%, and CP and ME varies from 40 to 60 and 6.5 to 8 g/kgDM, respectively.

Table 3.4. Nutritional parameters of New Zealand straws. (Sources: Holmes and Wilson[1] (1987); Ulyatt et al[2]. (1980).

Straw type	Sou[a]	DM[b]	DMD[c]	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
		%	%	------------Grams per kg DM---------					
Barley	1	85	40-50	40	6.5	3.0	0.8	1.7	1.1
Barley	2	85		40	7.0				
Wheat	1	85		40	7.0				
Maize stover	1	85	40-50	50	7.5	6.0	1.0	4.5	0.7
Corn stover	2	85		50	7.0				
Pea	1	85	40-50	80	7.0	16.0	1.2		
Ryegrass	2	85		60	8.0				
Ryegrass	1	85	40-50	60	7.5	4.0	3.0	1.5	1.5
Oats	2	85		40	7.0				

a = Source, b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.5 By-products

Products obtained after the processing of plant and animal materials for food are called by-products. The feeding value of industry by-products can vary considerably. This variation is strongly influenced by the original product and by the method of processing (De Visser and Steg 1988).

In New Zealand, Bramwell et al. (1993) analysed the feeding value of horticultural products such as apple pulp, apple pomace, carrots, rejected kiwifruit and corn. The authors found that horticultural by-products have a high feeding potential for ruminants (Table 3.5). New Zealand has a large and expanding horticultural industry which produces a range of by-products (Table 3.5) that are suitable for livestock feeding.

A short term experiment (Holmes et al. 1994) at Massey University showed that lactation could be prolonged and milk production increased when pasture was supplemented with a 50:50 mixture of grass silage and apple pomace. The milk production benefits exceeded estimated milksolids value associated with a loss in pasture cover and the failure of cows to gain condition which occurred because lactation was extended by 32 days.

The information presented in Table 3.5 highlights the high energy value (over 11 MJME) and digestibility (over 70%) of some horticultural by-products, especially derivatives of apples, pears, peaches and kiwifruit. Crude protein contents, however, tend to be low (less than 10%). These products have potential to complement high quality fresh pasture which have high levels of crude protein. Thus appropriate by-products could help to provide grazing animals with a balanced diet. Also, because they are a "waste" material they are usually inexpensive compared to more traditional supplements such as hay and silage. Brewer's grain may be a suitable product to supplement grazing dairy cows, it has a high CP (25%), but around 40% of that protein is "by-pass" protein that can help to balance the amino-acid profile of the cow (Lean 1987). Brewer's grain also contains an acceptable level of ME (10 MJ/kgDM).

Table 3.5. Nutritional parameters of New Zealand by-products. (Sources: Bramwell et al[1]. (1993); Ulyatt et al[2]. (1980); Parker and Edwards[3] (1993) *pers.comm.*; Wilkins[4] (1993); Farm Facts[5] (1993); Holmes and Wilson[6] (1987)).

Name	Sou[a]	DM[b] %	DMD[c] %	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
				----------Grams per kg DM----------					
Apple bucher	4	40	86.1	10	13.1	0.9	0.9		
Apple pomace	1,4	70	74.4	61	13.7	0.9	0.9		
Apple"silo"pomace	3	23							
Apple Fresh pomace	3	21							
Apple pressings	1,4	89	89	47	13	0.9	0.9		
Apple pulp	1,4	25	74	60	8.4	0.9	0.9		
Apple pulp dried	1	89		33	9.5				
Apples	2	18		30	11.1				
Brewer's grain	2	35		250	10.0				
Brewer's grain	6	24		230	10.0	3	6.1	1	2
Citrus pulp	2,4	18	92	70	12.1	18.6	1.1	1.50	0.9
Citrus pulp	1	89		78	10.7				
Grape Pomace	2	38		140	5.2				
Grape pressings	1	80		142					
Grape pulp	1,4	91	91	33	4.8	0.4	0.5		0.8
Kiwifruit	5	15		50	11.5				
Kiwifruit pulp	4	16	44.5	100	8.6				
Kiwifruit silage	4	21	16.2	106	11.0				
Kiwifruit slices	4	16	90.8	100	12.9				
Maize husks	2	90		40	9.0				
Molasses	6	75		40	12.0	12	1	4.3	1.5
Peaches	4	80		50	12.0				
Pears	4	88		56	13.2				
Peas	2	18		140	10.9				
Potato offal dried	1	94		117					
Sugar beet pulp	2	11		120	10.2				
Tomatoes	4	13		235	11.4	3.9	5.5	1.8	
Winery pomace	1,4	94	93.5	112	7.3				

a = Source, b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.6 Concentrates

Concentrates are feedstuffs that contain a considerable quantity of energy and/or protein as a percentage of total nutrients. These are not widely used for livestock feeding in New Zealand because their cost is high relative to other feeds. High energy feedstuffs generally have a low concentration of protein. The energy in high energy concentrates comes from water soluble carbohydrates and fats (Church and Pond 1988). High energy concentrates are mainly represented by cereal grains and milling by-products. They are high in both DM content and digestibility (Holmes and Wilson 1987).

High protein concentrates (meals) are often derived from animal and plant sources processed as either animal feeds (fish meal) or industry by-products (blood meal, oilseed meal). Generally, protein of animal origin contains an important amount of rumen undegradable protein especially if it has been treated when dried. Nevertheless, the process for producing fish and meat meals can strongly influence their nutritive value and uniformity of quality.

Concentrate quality generally varies less than that of pasture. However, cereal concentrate composition also depends on plant variety, climate and fertiliser factors. The nutritional characteristics of New Zealand concentrates are presented in Table 3.6.

A wide range in the nutritional value of the same feeds is evident for some feeds. For example, barley is reported by three different authors to have widely different values for energy, crude protein and minerals. The same situation occurs for maize, oats, wheat and bran. These values highlight the variability in the nutritional characteristics of feeds that may be associated with environmental and management factors (see earlier discussion). It is important that this variability is accounted for in feeding programmes if sustained high animal performance is to be achieved.

Table 3.6. Nutritional parameters of New Zealand concentrates. (Sources: (Ulyatt et al[1]. (1980); Holmes and Wilson[2] (1987); Wilson[3] (1978); Harris and Douglas[4] (1981); James[5] et al. (1987)).

Name	Sou[a]	DM[b]	DMD[c]	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
		%	%	--------Grams per kg DM----------					
Barley	1	85		120	12.5				
Barley	4	86		97	10.7	0.5	3.8	1.5	0.2
Barley	2	86	85	110	13.0	0.6	4.4	1.8	0.3
Bran	1	85		170	9.6				
Bran (Wheat)	2	86		160	9.8	1.0	12.0	6.0	0.4
Buttermilk powder	1	93		340	13.2				
Dried blood	1	90		900	10.0				
Fish meal	1	92		750	11.5				
Grass meal	3	85		180	10.0				
Linseed cake	2	87		300	12.0	4.4	8.0	6.0	0.7
Linseed cake	1	85		350	12.0				
Lucerne meal	1	85		200	10.0				
Lucerne meal	2	87		200	11.0	16.0	3.0	3.0	1.5
Maize	1	85		100	14.0				
Maize	4	86		73	11.0		3.6	1.7	0.0
Maize	2	86		80	13.6		4.2	2.0	0.0
Meat meal	1	94		600	10.0				
Meat&bone meal	2	94		500	10.7	103	50.0	12.0	7.0
Oats	4	86		112	11.0	0.9	3.3	1.2	0.1
Oats	2	86		130	11.5	1.1	3.9	1.4	0.1

Name	Sou[a]	DM[b]	DMD[c]	CP[d]	MEMJ[e]	Ca[f]	P[g]	Mg[h]	Na[i]
		%	%	--------Grams per kg DM----------					
Oats	1	85		120	11.5				
Peas	2	87		240	13.0	1.4	4.3	1.7	0.1
Peas	1	85		300	13.0				
Peas	4	88		216	11.0	1.3	3.7	1.5	0.1
Pollard	1	85		180	12.2				
Skim milk powder	2	94		350	13.0	12.5	10.0	1.2	6.0
Skim milk powder	1	94		360	12.8				
Soya beans	2	90		500	12.9	2.7	5.5	2.6	0.1
Soya beans	4	91		328	14.2	1.5	5.0	2.3	0.1
Triticale"aranui"	5	87		132	14.5	0.4	3.7	1.4	0.1
Triticale"karere"	5	86		146	15.4	0.3	3.9	1.3	0.1
Wheat	2	86		130	12.6	0.6	4.0	1.6	0.1
Wheat	1	85		120	12.5				
Wheat	4	87		117	10.6	0.5	3.5	1.4	0.1

a = source, b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.7 Crops

Crops are often planted with the aim of feeding livestock *in situ*, but they may also be harvested and stored in the form of hay, silage or grain to be fed during periods of pasture shortage.

The nutrient composition of crops is mainly influenced by the stage of growth at which the crop is grazed or harvested. Other factors influencing the nutrient composition of crops are variety, fertilisation and cultivation method (Holmes and Wilson 1987).

Forage crops include cereal crops and root crops. The main forage cereal fed to dairy cows in New Zealand is maize. This is a C4 plant with high DM yield potential (in excess of 25t DM/ha at favourable sites), moderate to large amounts of energy content and medium to low protein levels (Lean 1987). In New Zealand maize is sometimes fed green to grazing dairy cows as a summer supplement (i.e. green-feed maize).

Root crops are characterised by high moisture content, low fibre and low calcium and phosphorus levels. They have a high content of readily available carbohydrates that can be used by ruminants (Church and Pond 1988). The high energy concentration of root crops makes them a suitable option to supplement grazing dairy cows. Root crops grow in relative short periods of time (70-120 days) and they can produce a substantial amount of gross energy (GE) per unit of area. The nutrient composition of New Zealand crops is presented in Table 3.7. Forage crops such as oats, lucerne, wheat, barley and sorghum provide an ME concentration of over 12 MJ/kgDM. Lucerne has a CP content in excess of 20%. Root crops, like swedes and turnips also have high ME concentrations.

Table 3.7. Nutritional parameters of some New Zealand crops. (Sources: Bramwell et al[1] (1993); Holmes and Wilson[2] (1987); Wilson[3] (1978); Ulyatt et al[4]. (1980); Wilkins[5] (1993); Joyce et al[6]. (1972); (Bryant et al[7]. (1983)).

Name	Sou[a]	DM[b]	DMD[c]	CP[d]	ME[e]MJ	Ca[f]	P[g]	Mg[h]	Na[i]
		%	%	--------Grams per kg DM----------					
Maize,1.3-1.6m	2	22	63	90	10.3	4.0	2.5	1.5	0.2
Maize,full bloom	4	24		100	9.8				
Maize milk	4	25		80	10.3				
Maize dough	4	28		80	10.4				
Lucerne,leafy	2	18	66	280	12.0	16.0	3.0	2.5	0.6
Lucerne 10-20%flower	2	23	55	220	10.0	13.0	2.8	2.4	0.5
Lucerne,inmature	4	15		250	12.0				
Lucerne pre bloom	4	17		220	11.5				
Lucerne early bloom	4	20		200	11.0				
Lucerne mid bloom	4	23		160	10.5				
Lucerne	7	16	60	240		16.5	3.4	2.7	1.3
Lucerne pressed	7	22	58	194		14.4	2.8	2.1	1
Lucern double pres.	7	27	57	178		13.2	2.4	1.7	0.9
Lucerne early veg.	6		76	298		11.9	4.3	1.8	0.2
Lucerne late veg.	6		72	264		12.1	3.7	1.6	0.3
Lucerne budformation	6		69	248		10.4	3.7	1.4	0.2
Lucerne10% flowering	6		62	227		13	3.3	1.3	0.1
Carrots	4	13		100	12.8				

Name	Sou[a]	DM[b]	DMD[c]	CP[d]	$ME_e MJ$	Ca[f]	P[g]	Mg[h]	Na[i]
		%	%	--------Grams per kg DM----------					
Choumoellier	2	15	83	145	11.5	15.0	2.4	2.7	3.3
Fodder beet whole	2	18		100	11.5	1.2	1.7		
Fodder radish	4	11		100	11.0				
Mangels,whole crop	4	13		160	12.5				
Mangolds	2	10		100	11.5	1.5	1.8	2.0	6.0
Potatoes	4	23		100	12.3				
Potatoes	2	24		90	12.0	0.3	2.5	1.0	1.0
Pumpkin	4	9		160	12.9				
Pumpkin	3	9		160	12.8				
Rape	2	17		160	12.0	15.0	4.0	0.7	0.5
Raw potato	1	21		104	11.5				
Swedes,bulbs	2	10	83	120	12.4	1.3	2.0	2.0	1.0
Swedes,tops	2	15	83	150	12.8	25.0	2.7	4.0	2.0
Swedes,whole crop	4	11		200	13.0				
Sweep lupins	4	15		170	10.0				
Turnips,bulbs	2	9	83	150	12.4	6.0	3.0	2.0	2.0
Turnips,tops	2	13	83	180	13	35	3.4	4.0	3.0
Turnips,whole crop	4	9		200	13				

a = Source, b = Dry matter, c= Dry matter digestibility, d = Crude protein, e = Metabolic energy in Mega joules, f = Calcium, g = Phosphorus, h = Magnesium, i = Sodium.

3.9 Conclusion

Information on the full range of nutritional characteristics for feeds suitable for livestock feeding in New Zealand is relatively scarce. The available data for most feeds is limited to 2-5 parameters. For pastures and green feeds, the information does not account for regional effects, and variation in quality throughout the year is not well documented.

Under the current system of feed analysis, based on ARC (1980), ME and digestibility are considered to be the key elements of feed quality. However, Muller (1993a) suggested that for ration balancing a much wider range of quality parameters need to be considered. These include protein (soluble, undegradable and degradable fractions), fibre components (neutral detergent fibre (NDF) and acid detergent fibre (ADF)), net energy of lactation (Non fibre carbohydrate and fat), minerals and vitamins. Linn and Martin (1991) stated that as a minimum any forage quality program for ration balancing should include DM, crude protein, ADF, NDF, calcium and phosphorus. Paterson et al. (1994) suggested that NDF and ADF can be used to determine forage quality. High forage quality is characterised by low values of NDF and ADF that allow for higher DM intakes. NDF composition also deserves consideration (Muller 1993a). Details on the NDF and ADF content of New Zealand feeds are generally not available.

The introduction of Near Infrared Reflectance Spectroscopy (NIRs) may help to develop a more detailed database of New Zealand feeds. NIRs offers the opportunity for rapid, reliable and low cost feed analysis for a wide range of nutritive parameters. These include DM%, protein, ADF, NDF, ADF-CP, ADF-Nitrogen and minerals like Ca and P (Shenk and Westerhaus 1994). NIRs measures the nutritive parameters of feeds by comparing the spectrum of near infrared reflectance of unknown samples with those from known samples obtained by traditional wet chemistry analysis. The cost and timeliness advantages of NIRs means that it is well suited to the development of farm ration balancing programmes in a grazing situation (Kellaway and Porta 1993), in a manner similar to that which is already extensively used for confined feeding conditions in the Northern Hemisphere (Linn and Martin 1991).

The development of a national pasture database from NIRs (and wet chemistry analysis) would also provide a more comprehensive description of pasture quality and this together with a feed quality service would provide farmers and consultants with more reliable estimates of pasture and supplements quality (Edwards and Parker 1994). This information can then be used to balance an animal's diet. It also provides the opportunity to determine harvesting date for either hay-or silage-making.

Chapter 4

Case farm simulations of management options to increase production per cow

4.1 Introduction

New Zealand dairy farmers are internationally regarded as being cost effective producers of milk (Murphy 1993). This is due to the utilisation of pasture grown *in situ* and an emphasis on per hectare production (Deane 1993). The consequent high stocking rates, relative to annual pasture growth and cow requirements, does not allow cows to maximise their intake of pasture, and per cow production averages only 160 kg milkfat or 280 kg MS/cow (Holmes and Hughes 1993). Another contributing factor is that average lactation lengths under this system of farming is far below those recommended overseas, being around 221 days for the 1992/93 season (LIC 1994). Scope exists to increase production per cow by improving diet quality and the level of intake of cows at critical times of the year (Edwards and Parker 1994) and by extending the lactation period (Holmes et al. 1994). However, the use of supplements other than pasture derivatives to increase per cow production is limited by costs (Holmes and Hughes 1993) and availability (see Chapter 3). Likewise, prolonging lactation length can increase total milk production in the current lactation at the expense of condition score and/or pasture cover (Gray et al. 1993) and hence cow performance over the next lactation (Grainger et al. 1982).

Dairy farms are dynamic systems in which management changes are difficult to evaluate in the context of whole farm productivity. Mathematical models enable the rapid and inexpensive analysis of alternative management systems. Simulation models of pasture based dairy farms, such as UDDER (Larcombe 1990a), can help to determine the likely outcome of changes to farm management (McKay 1994). The model predicts herd milk production in 10 day time steps based on specified pasture accumulation rates and management conditions for the case farm (Larcombe 1990b). Model predictions include the growth and quality of pasture, animal intake and the partitioning of energy towards milk production, maintenance, growth and pregnancy (Larcombe 1990a). Recommendations from ARC (1980) are used to estimate energy partitioning and the cow's requirements for maintenance, pregnancy and growth. The latter are discounted from total energy intake and residual energy is used to predict milk production (Larcombe 1990b).

An experiment was conducted using UDDER to evaluate alternative management options to profitably increase per cow production at Massey University's No.4 dairy farm. The options studied included delaying drying-off dates and strategic supplementation of the diet at critical times of the year (early and late lactation).

4.2 Methodology

Description of the case farm

Massey University's No.4 dairy farm is located 3 km south west of Palmerston North at an altitude of 40 masl, and receives an average annual rainfall of 1000 mm. It is operated as two management units. The present study was conducted on Lovelock farm, a 90 hectare unit supporting a seasonal dairy herd. Pasture and animal performance are monitored closely to assist management decision making (Ridler and Hurley 1984). The farm is divided into paddocks of approximately 2.5 ha that contain mainly ryegrass-white clover pastures. Soils are mainly from Tokomaru silt loam, Ohakea silt loam and Shannon silt loam. These soils have poor natural drainage and a tendency to dry out during the summer. They have been tile and mole drained to improve winter and spring productivity. Fertiliser inputs include the use of urea to boost pasture production in spring and autumn and DAP and lime to increase overall soil fertility.

Stock numbers wintered in 1993 included a herd of 235 milking cows plus 41 rising 2 year old heifers (grazed off) and 44 rising 1 year old heifers. Cows start calving in early August at a condition score of 4.6 units and by the end of the month 71.5% have calved; late calvers are induced so that calving is normally completed by the end of September. Mating starts in mid-October and the herd is dried off on the basis of condition score and pasture availability usually near the end of April. Approximately 35% of the cows are grazed off the farm for two months during the winter (June and July).

Herd supplementary feed management includes the use of maize silage to milkers at a rate of 3 kg DM/cow day from early January to mid-February. From mid- February to early April cows are fed with a summer crop, usually green fed maize. Winter feeding includes 4 kg DM/cow day of pasture silage or hay from drying-off until calving.

The management information described above, plus the costs of the different inputs and the 1993/94 season's milk price (NZ$5.60 kg milkfat), were entered into UDDER to simulate an average year for the farm. The results of this simulation were analysed jointly with the farm supervisor and adjustments were made to calibrate model output to "fit" the farm monitoring data (i.e. milk production, pasture cover, condition score). This produced a "base" model for an average year for the farm (Appendix 1).

Next different management alternatives to increase per cow production were evaluated relative to the base situation (average year). This was performed sequentially with a single variable changed for each simulation run in a factorial experimental design. This approach allowed the effect of changes in a single variable on the overall system to be quantified. Figure 4.1 illustrates the methodology followed.

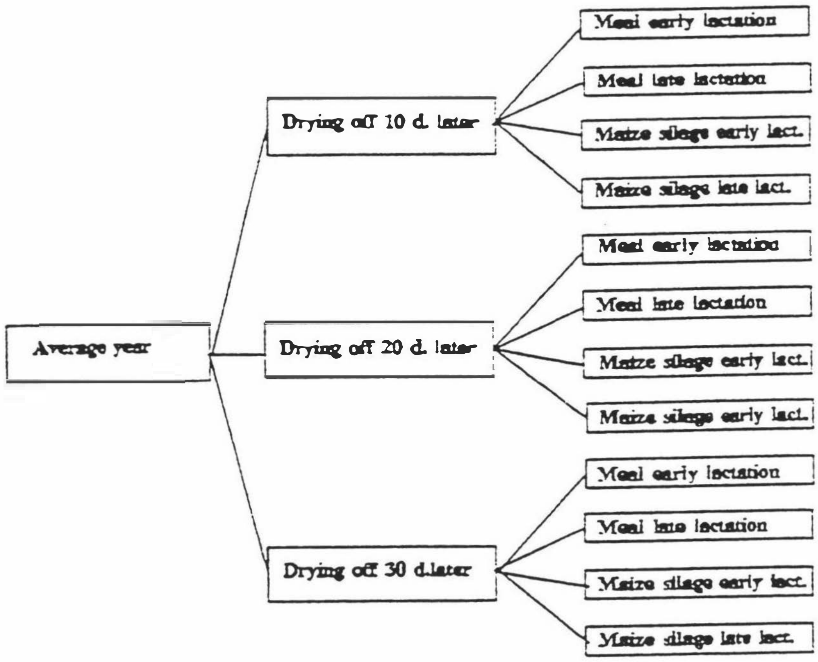

Figure 4.1. Experimental design used to evaluate effect of alternative management options with UDDER.

The first variable to be manipulated was drying-off date. It was extended by 10 (DO10), 20 (DO20) and 30 (DO30) days, respectively. The same drying-off pattern for the herd as for an average year was followed for the three simulations. Next each drying-off option was simulated for the feeding of meal in early lactation (MEE), meal in late lactation (MEL), maize silage in early lactation (MSE) and maize silage in late lactation (MSL). Early lactation supplementation started on 11 August and finished on 21 September. Late lactation supplementation started on 11 April and finished at drying-off (10, 20, 30 May for strategies DO10, DO20 and DO30 respectively). Maize silage was assumed to have a digestibility of 73% and was fed at 4 kg/DM per cow. Meal had an 80% digestibility and was fed at 2 kg/DM per cow in both early and late lactation options. The variables reported from the UDDER output were per cow production, cow condition score (CS), average pasture cover (APC), and gross margin (GM) per cow and per hectare.

4.3 Results

Prolonging lactation length by delaying drying-off date increased milk production per cow for each option studied (Table 4.1) with the largest increase (10.4 kg MF/cow year) being obtained for 30 extra days in milk (Appendix 2). Cow condition (CS) score decreased progressively as lactation was prolonged, and reached a minimum level of 4.3 units for DO30 at the end of the season. Similarly, average pasture cover (APC) decreased progressively as drying-off date was delayed; the lowest APC (2493 kg DM/ha) being achieved for DO30 (Table 4.1). Gross margin per cow and per hectare reached maximum levels for the longest lactation length at NZ$ 500.70 per cow and NZ$ 1307.37 per hectare respectively.

Table 4.1. Effects of delaying drying-off dates (10, 20 and 30 days) on production per cow, average cow condition score, average pasture cover and gross margin per cow and per hectare.

Simulation option	Milk production (kg/MFcow)	Condition score (units)	Average pasture cover (kg DM/ha)	Gross Margin (NZ$/cow)	(NZ$/ha)
Average year	161.9	4.6	2837	436.14	1138.81
Avg. year plus 10 days (DO10)	165.4	4.5	2731	457.33	1194.15
Avg. year plus 20 days (DO20)	168.8	4.4	2618	478.60	1249.60
Avg. year plus 30 days (DO30)	172.3	4.3	2493	500.70	1307.37

Supplementation with either maize silage or meal increased per cow production in both early and late lactation when cows were dried of 10 days later (Table 4.2). The largest response (10.1 kg MF/cow year) was obtained when cows were supplemented with maize silage in early lactation. The four strategies for supplementary feeding for DO10 increased average cow CS; the largest increase in CS (+0.3 units) being obtained with maize silage in early lactation and a ten day longer lactation length (i.e. DO10+MSE). The use of supplements increased APC for all strategies, This increase was greater when cows were supplemented with maize silage in early lactation (2915 kg DM/ha) and late lactation (2863 kg DM/ha). These values exceeded the APC recorded for the average year (Table 4.2). The highest GM per cow and per hectare was obtained through supplementing cows with maize silage in early lactation (NZ$ 30.93 per cow; NZ$ 80.77 per ha.) and meal in early lactation (NZ$ 13.27 per cow; NZ$ 34.64 per ha) compared with an average year. Overall, the best response in terms of milk production, CS, APC and GM was obtained when cows were supplemented in early lactation with maize silage (Table 4.2).

Table 4.2. Effect of delaying drying-off date by 10 days (DO10) and supplementing with meal (ME) and maize silage (MS) in early (E) and late (L) lactation.

Simulation option	Milk production (kg/MFcow)	Condition score (units)	Average pasture cover (kg DM/ha)	Gross margin (NZ$/cow)	(NZ$/ha)
Average year	161.9	4.6	2837	436.14	1138.81
DO10+MEE	170.2	4.7	2791	449.41	1173.45
DO10+MEL	165.9	4.6	2791	446.04	1164.67
DO10+MSE	172.0	4.9	2915	467.07	1219.58
DO10+MSL	165.5	4.6	2907	446.80	1166.63

The corresponding effects of supplementing the diet of cows where lactation was extended 20 days (DO20) are shown in Table 4.3. Supplementation with either maize silage or meal in both early and late lactation increased per cow production. Greater responses in milk production per cow were obtained with maize silage in early lactation (+14 kg MF) and meal early lactation (+12 kg MF). Milk production responses for late lactation supplementation were small for both supplement types. Average cow CS was improved by the use of supplements but remained below from that of the average year when supplements were used in late lactation. The largest response in CS was obtained from feeding maize silage in early lactation (+0.2 CS units). Supplements increased APC for all strategies relative to DO20, but only maize silage supplementation during late lactation increased APC to a level above that of the average year. The best economic response was obtained by supplementing cows with maize silage in early lactation. The gross margin per cow and per hectare was increased by NZ$ 54.57 and NZ$ 142.48 respectively compared with an average year.

Table 4.3. Effect of delaying drying-off date by 20 days (DO20) and supplementing with meal (ME) and maize silage (MS) in early (E) or late (L) lactation.

Simulation option	Milk production (kg/MFcow)	Condition score (units)	Average pasture cover (kg DM/ha)	Gross margin	
				(NZ$/cow)	(NZ$/ha)
Average year	161.9	4.6	2837	436.14	1138.81
DO20	168.8	4.4	2618	478.60	1249.60
DO20+MEE	173.9	4.6	2672	471.80	1231.87
DO20+MEL	169.5	4.5	2702	462.80	1208.43
DO20+MSE	175.9	4.8	2788	490.71	1281.29
DO20+MSL	168.9	4.5	2863	463.65	1210.64

The effects of feeding supplements in early and late lactation on production parameters where drying-off was extended by 30 days are shown in Table 4.4. The greatest response in milk production (17.9 kg/MF per cow) was obtained by supplementing cows in early lactation with maize silage (Figure 4.2 and Appendix 3). Supplementation increased average cow condition score for all strategies when compared with strategy DO30, although, only the use of maize silage in early lactation increased CS above that of the average year (i.e. 4.7 vs 4.6 CS units) (Figure 4.3). None of the feeding options resulted in APC being above that of the average year. The use of maize silage in early lactation increased GM per cow and per hectare by NZ$ 78.90 and NZ$ 205.99 respectively compared with an average year.

Table 4.4. Effect of delaying drying-off date by 30 days (DO30) and supplementing with meal (ME) and maize silage (MS) in early (E) or late (L) lactation.

Simulation option	Milk production (kg/MFcow)	Condition score (units)	Average pasture cover (kg DM/ha)	Gross margin (NZ$/cow)	(NZ$/ha)
Average year	161.9	4.6	2837	436.14	1138.81
DO30	172.3	4.3	2493	500.70	1307.37
DO30+MEE	177.5	4.5	2545	494.80	1291.99
DO30+MEL	173.3	4.5	2608	479.52	1252.09
DO30+MSE	179.8	4.7	2655	515.04	1344.80
DO30+MSL	172.5	4.4	2823	480.45	1254.50

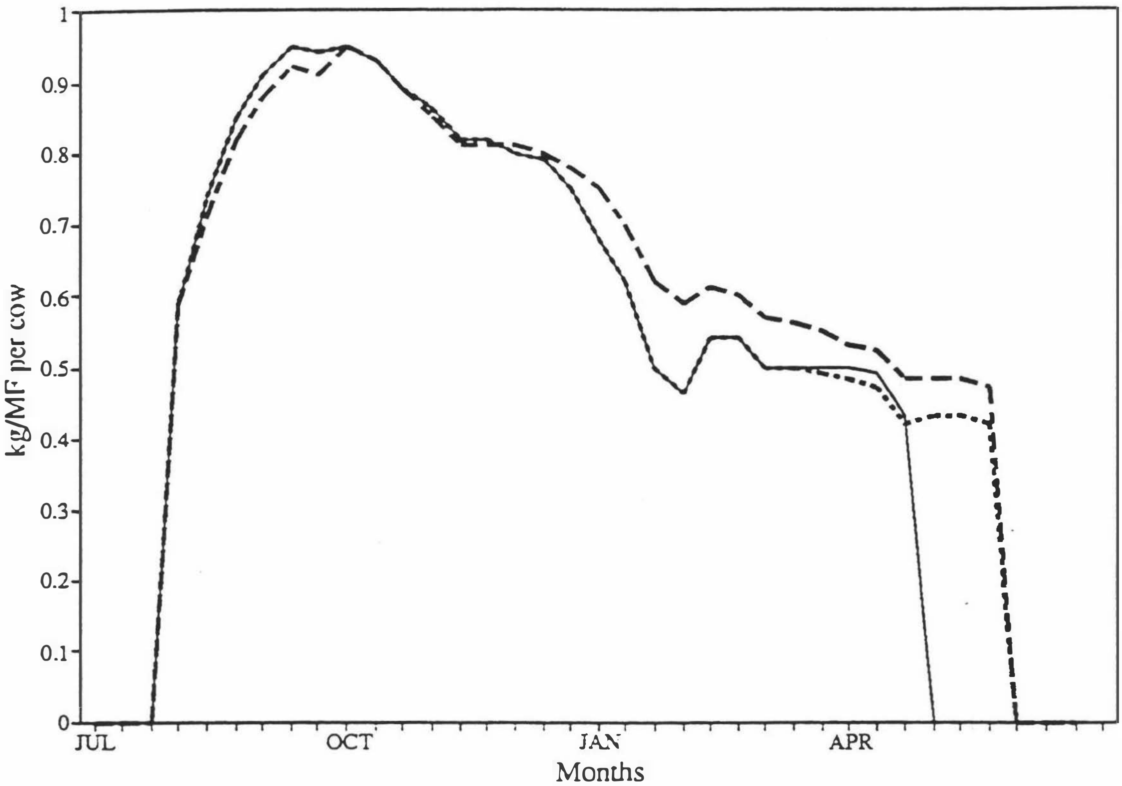

Figure 4.2. Milk production curves for an average year (—), drying-off 30 days later (DO30) (...) and DO30 plus maize silage in early lactation (- -).

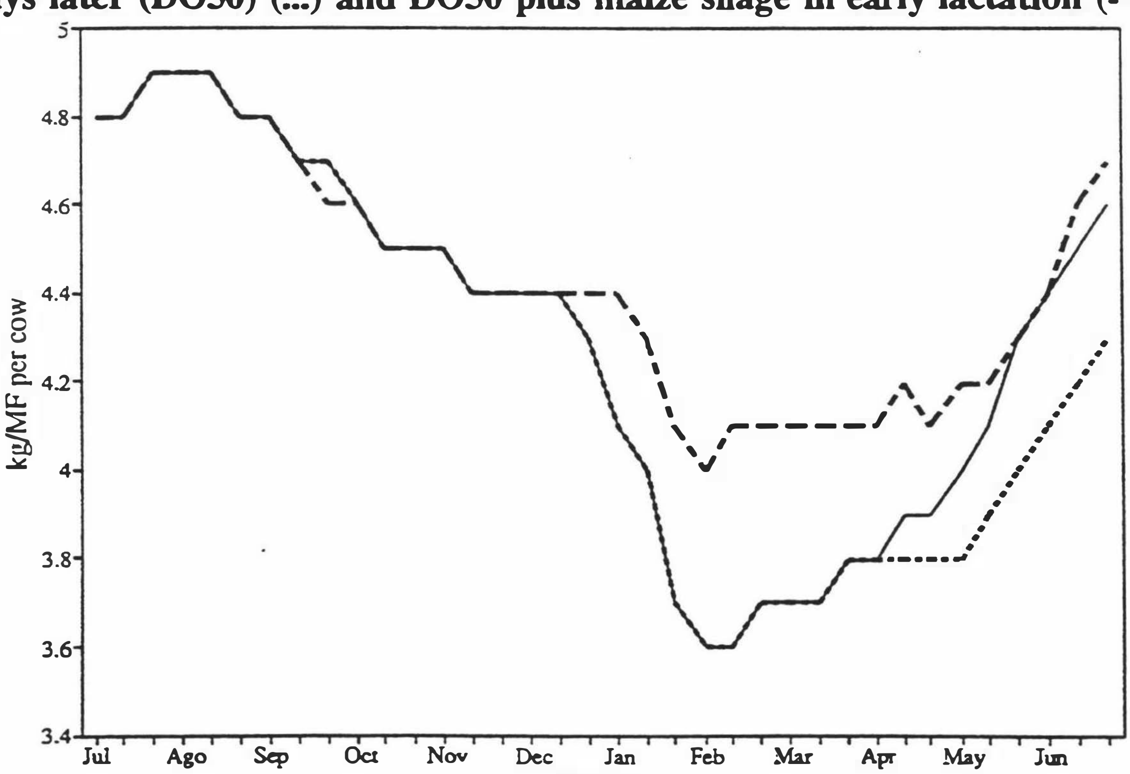

Figure 4.3. Average cow condition score for an average year (—), drying-off 30 days later (DO30) (...) and DO30 plus maize silage in early lactation (- -).

4.4 Discussion

The simulation of alternative management strategies for No.4 dairy farm indicated that per cow production could be profitably improved on the case study farm by extending lactation by 30 days (i.e. drying on 31 May) and feeding maize silage at 4 kg DM/cow per day in early lactation. The following general discussion is based on this alternative. First, some clarification on the outputs from UDDER is needed. UDDER provides an approximation to reality; it is an energy-based model and assumes that under temperate grazing conditions energy is limiting production. Thus, it does not consider other important nutritional parameters (protein, fibre, minerals and vitamins) that might limit productivity (see Chapter 2).

Delaying drying-off date increased milk production at the expense of cow condition score and average pasture cover (Table 4.1). Increased milksolids production was therefore obtained from the mobilisation of energy from body reserves towards milk production and by allowing cows to graze pastures to a lower post-grazing residual mass than under normal late lactation management.

Reduced condition score and average pasture cover can negatively influence milk production during the next lactation (Grainger et al. 1982; Gray et al. 1993). Care therefore needs to exercised to ensure current production is not achieved at the expense of the next lactation. The model indicated that maize silage feeding during early lactation produced a carry-over effect on milk production from mid-lactation until drying-off. The pasture cover output (Figure 4.4) shows that this occurred because feeding maize silage in early lactation enabled extra pasture (relative to the base situation) to be transferred to the late summer, traditionally a dry period with low rates of pasture growth at No.4 dairy farm. In addition, the cows may have achieved a more balanced diet in early lactation as a consequence of the inclusion of maize silage (i.e. decrease in the amount of RDP intake that can improve overall rumen efficiency), although the model is unable to simulate this effect. Higher planes of nutrition in early lactation can have positive effects over the whole lactation (Broster and Thomas 1981; Broster and Broster 1984; Kellaway and Porta 1993).

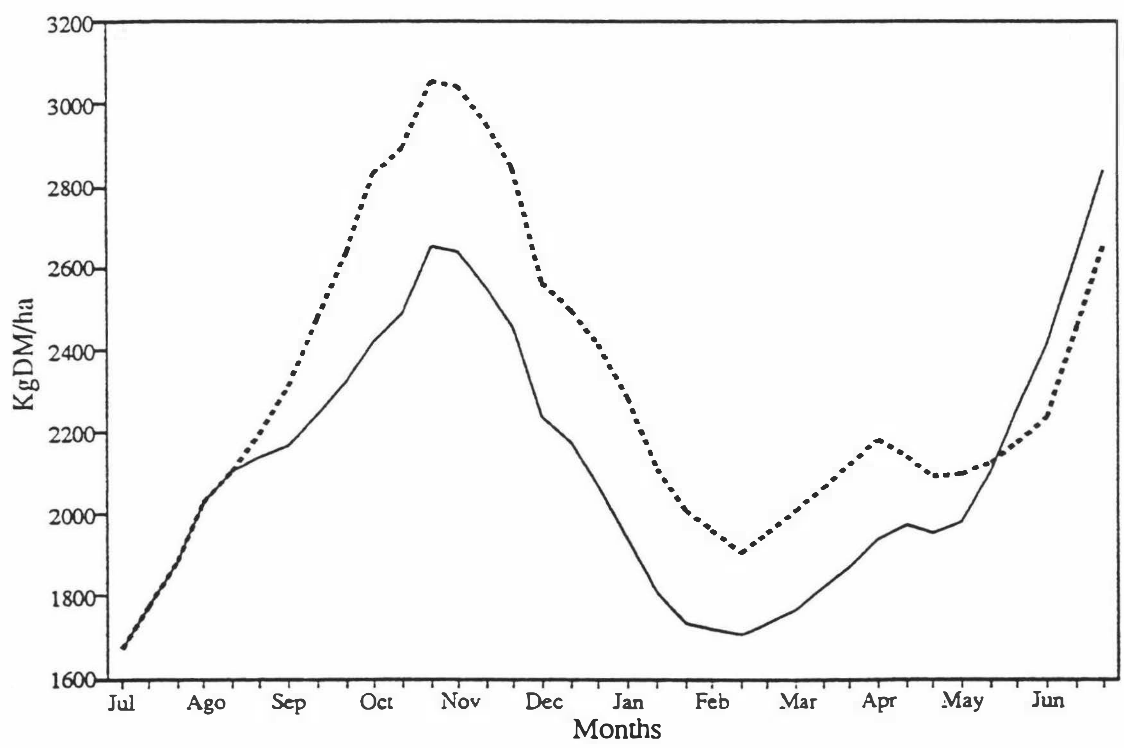

Figure 4.4. Average pasture cover for an average year (—),and a strategy with 30 days extra milk and maize silage feeding in early lactation (...).

Cows fed maize silage in early lactation consistently had higher pasture DM intakes in mid-and late-lactation (Figure 4.5). This resulted in higher pasture utilisation, and cows under this management system consumed 8.7 tonnes DM per hectare per year compared with 8.4 tonnes DM per hectare for an average year. Senescence and decay, which are considered by UDDER, were not increased because of higher levels of average pasture cover during the summer.

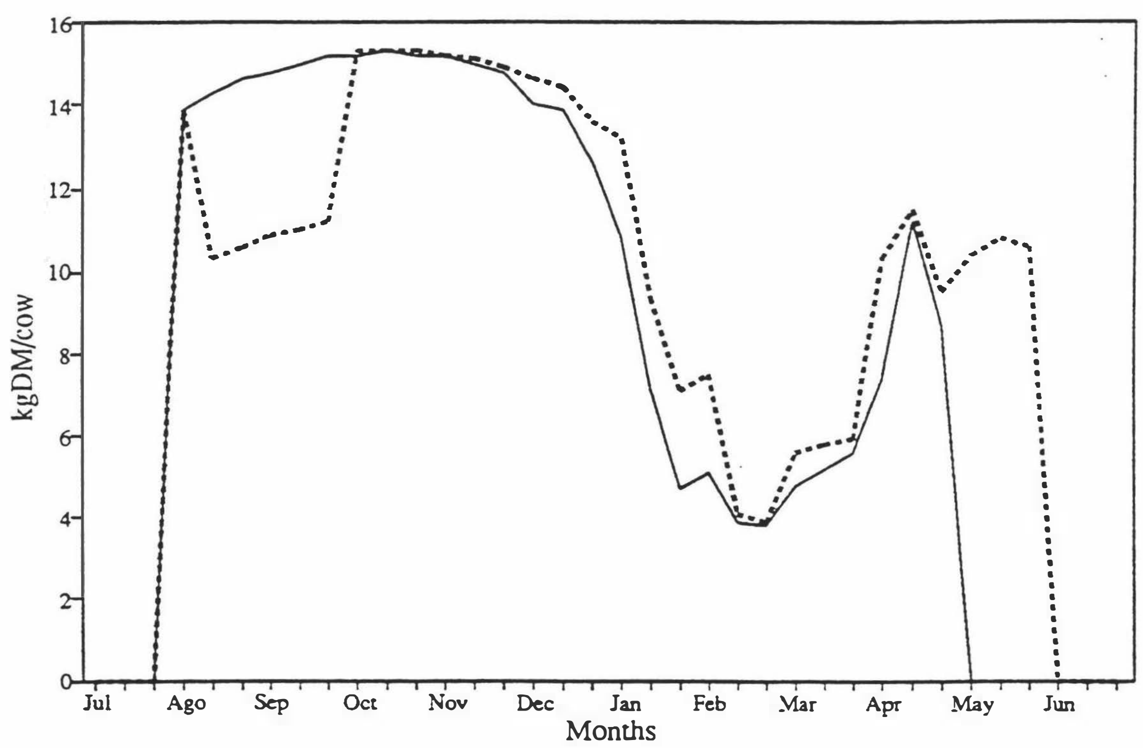

Figure 4.5. Average pasture DM intake for an average year (—), and a strategy with 30 days extra milk and maize silage feeding in early lactation (...).

Peak milk production of cows for an average year, DO30 and DO30+MSE (Figure 4.2) was similar. Feeding cows maize silage did not generate a higher peak production, because cow DM and metabolizable energy (ME) intake were similar in early lactation (Figure 4.5 and 4.6 respectively). However, ME intake (Figure 4.6) was greater in mid- and late-lactation when cows were supplemented with maize silage in early lactation. This could be explained by the fact that feeding cows maize silage without a supplementary source of protein may cause them to fatten rather than produce milk (Lean 1993).

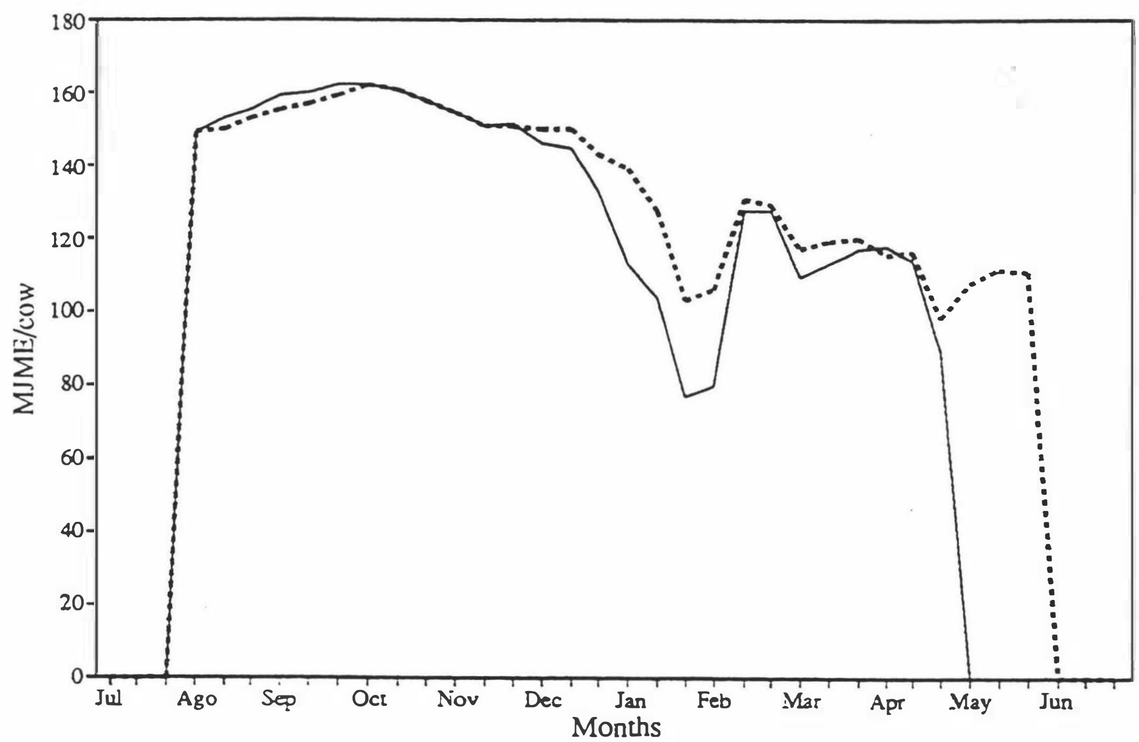

Figure 4.6. Metabolizable energy intake for an average year (—), and a strategy with 30 days extra milk and maize silage feeding in early lactation (...).

Similarly, the higher plane of nutrition for cows in strategy DO30+MSE explains the greater average cow condition score throughout the lactation (Figure 4.3). Feeding low protein supplements (i.e. maize silage) may produce energy-protein imbalances in high producing cows (Lean 1993). The nutritional adequacy of this early lactation diet is evaluated in detail in the next chapter.

UDDER does not consider the effects of feeding supplements on reproductive performance. However, the calving pattern and number of cows in-calf both significantly affect farm returns, through number of days in milk and the level of involuntary culling or the need for induction (Parker and Edwards 1994). Cows on a high plane of nutrition should achieve an improved reproductive performance through a shorter interval from calving to mating relative to poorly fed cows (Lean 1991; McDougall 1993). This is because cows loose body condition less rapidly when they are properly fed during early lactation (Muller 1993a). Likewise, supplementation of high quality spring pasture with maize silage may decrease the intake of rumen degradable protein RDP (Satter et al. 1992), and help to enhance reproductive performance through improved conception rate and embryo survival (Williamson and Fernandez-Baca 1992; Moller et al. 1993). As well, overall rumen efficiency, may be improved because of the reduced amount of nitrogen excreted as urea through tissue fluids. Neither of these carry-over effects can be quantified by UDDER, but they might be achievable if the cows on the case farm are provided with an improved diet during the early lactation period.

Average pasture cover for the strategy DO30+MSE remained lower than that for the average year (Figure 4.4). Feeding maize silage in late lactation increased APC through additional feed inputs to the system. Similarly, a decreased cow DM intake in late lactation could have helped to increase the cover on the farm. Increases in APC have been reported as one of the carry-over effects of pasture supplementation (Kellaway and Porta 1993). Maize silage supplementation produced greater responses in APC than meal supplementation; this can be attributed to a larger substitution rate effect assumed in the model for maize silage (1) than for meal (0.75) (Rogers (1985); Phillips (1988); Mayne (1990)). Therefore the use of maize silage as a supplementary feed can increase post-grazing pasture masses (see earlier discussion).

The only strategy that consistently increased the gross margin over those of the average farm (while keeping satisfactory levels for average cow CS at 4.7 units and APC at 2655 kgDM/ha) was drying-off cows 30 days later and feeding maize silage in early lactation. This strategy produced an extra 17.9 kgMF per cow and NZ$ 78.90 per cow compared to the base year. This represented additional income for the farm of NZ$ 18,540 per year.

Milk production was increased from mid-lactation onwards by feeding maize silage in early lactation (Figure 4.2). Under a seasonal pricing scheme, such as that of Bay Milk Products or Tui Milk Products, this extra milk would receive a higher price. The simulations carried out using meal did not favour the inclusion of this feed in the diet due to its high cost (NZ$450 per tonne) compared to maize silage (NZ$180 per tonne).

However, UDDER did not consider the extra labour required to feed maize silage for 50 days in early spring (usually a period of high labour demand). The availability and costs of this labour should be quantified (e.g. 2 hours per day at NZ$10 per hour for 50 days equates to NZ$500 or NZ$2.12 per cow). Similarly, the extra costs involved in running the machinery to deliver the silage from the pit to the troughs should be accounted for (e.g. 2 hours per day at NZ$18.52 per hour for 50 days equates to NZ$926 or NZ$3.94 per cow).

The present study was conducted based on an "average" year. In reality, between year variation in monthly pasture growth rates is reasonably large. The management system described earlier may generate better results in years with poor pasture growth rates in spring and summer, while on the other hand, in years with exceptional growth rates the benefits of this system could be overestimated. Stochastic models of New Zealand pasture-based dairy farm systems are not available. This would be a useful improvement to UDDER.

4.5 Conclusions

The case farm study simulation reported here suggests that there is scope to increase production profitably by increasing lactation length and supplementing the diet with high quality maize silage. These changes to feeding management would not be difficult to implement on the case study farm. For example, maize silage can be contracted from a silage producer, analysed for quality characteristics and paid for accordingly (Parker and Edwards 1994). The proposed system of maize silage feeding does not involve extra capital expenditure and can readily be discontinued if the cost: price ratio for milksolids changes. Maize silage is already fed on the farm during the summer as part of its feeding policy, and there is no need to build extra facilities because a winter feeding pad and troughs are available (MacDonald, A. 1994 *pers.comm.*).

While the results of this simulation study apply to No.4 dairy farm, some general considerations can be made with respect to the wider context of dairying in New Zealand. Research could be conducted at different localities to measure the benefits of feeding high quality maize silage (> 10.5 MJME/kgDM) to high breeding index cows (BI > 125) in early spring while grazing high quality pastures. This could complement intensive indoor studies with fistulated animals to confirm wether the use of maize silage balanced the diet of cows grazing high quality temperate pastures (Satter et al. 1992; Moller et al. 1993).

UDDER's primary weaknesses are that it assumes that the main limitation for milk production on a dairy farm is energy and it does not account for between years effects of variable pasture growth. The former means that simulation results can be misleading if factors other than energy are limiting milk production. In addition, UDDER does not consider improvements in herd reproductive performance that might be achieved through the use of supplements (MacCallum 1994). In some circumstances these effects can be more important than improvements in overall production per cow or economic performance (Parker and Edwards 1994). The adequacy of supplementing the diet of cows grazing high quality pastures with maize silage in early lactation is analysed in the next chapter using the ration balancing program CAMDAIRY.

Chapter 5

Test runs with CAMDAIRY

5.1 Introduction

Dairy farmers in New Zealand using pasture-only feeding systems must overcome the constraint imposed by variation in pasture quantity and quality to increase production per cow (Chapter 1, Chapter 2). Ration formulation, the process of balancing animal diets to correct for nutrient and mineral deficiencies, offers an opportunity to reduce these limitations as described in previous chapters (see Chapter 2 in particular). Generally, ration formulation is carried out using computer programs that incorporate linear programming techniques to find the feed mix that optimises profit or minimises feed cost.

In Chapter 4 management strategies to profitably increase production per cow on Massey University's No.4 dairy farm were evaluated with UDDER. While the analysis indicated that maize silage feeding in early spring and an extended lactation would achieve this aim, UDDER was not able to adequately represent the nutritional limitations of the proposed feeding policy for the herd, basically because it is an energy-based model. Therefore, the purpose of this chapter is to carry out further analyses of the management options evaluated with UDDER using the ration balancing model "CAMDAIRY" (Irwin and Kellaway 1991).

5.2 Description of the model

CAMDAIRY is a personal computer model that uses linear programming to formulate rations while satisfying nutrient requirements and other constraints on feeds or nutritional parameters. Linear programming models like CAMDAIRY deal with static situations (i.e. it gives an optimum solution for one day only); in contrast, UDDER deals with dynamic situations (i.e. it assists to anticipate the effects of changes to farm, animal or environmental variables of a dairy farm in a whole year, in time steps of 10 days). Both CAMDAIRY and UDDER are deterministic (i.e. they do not consider variability); in reality farming systems are stochastic.

An advantage of CAMDAIRY is the prediction of tissue mobilization and the incorporation of energy and protein from that tissue to the pool of dietary nutrients (Hulme et al. 1986). However, one disadvantage of the program is that it does not penalize the energy spent in removing excess N when high RDP diets are fed. As a consequence, CAMDAIRY may overestimate the likely milk production response of cows fed pasture-based diets.

CAMDAIRY includes three main programs for analysing dairy cow rations; maximum profit formulation, least cost formulation and prediction of performance and profit (Hulme et al. 1986). The first two modules are for formulating rations that obtain maximum returns or fulfill dairy cow requirements at the minimum cost. The module "prediction of performance and profit" calculates the likely milk output from a specific diet. It also specifies nutrients (i.e. energy, RDP, UDP, calcium and phosphorus) that are limiting production. In analysing a diet the program shows the likely milk production from energy, RDP, UDP, Ca and P. However, the assumptions to estimate milk production from RDP and UDP are not clear, because the available protein for maintenance and milk production comes from a total protein "pool" (incorporating both UDP and RDP) in the small intestine and not from UDP and RDP independently (H. Varela-Alvarez 1995 *pers. comm*).

Daily cow requirements are determined by the program from user inputs for animal liveweight, peak milk production potential, cow breed, milkfat concentration, stage of lactation, and activity. Other important parameters for the determination of milk production are animal DM intake and the nutritional characteristics of the diet fed. Data from Massey University's No.4 dairy farm for these variables were used in the analysis.

5.3 Methodology

Information from the UDDER output for the "average year" strategy (see Chapter 4 for details) was entered into CAMDAIRY. This included information on farm, animal and feed characteristics. Farm data included details of cow breed, milkfat and protein test, potential peak milk yield and milk price. Animal data included the number of cows and heifers, cow liveweight, average cow condition score, stage of lactation, weeks in calf, activity, and cow liveweight gain.

Nutritional characteristics of feeds included: dry matter percentage, crude protein percentage, protein degradability, metabolizable energy concentration, fibre fractions (ADF and NDF) and mineral concentration which included macro-and micro-elements. Information on the nutritional characteristics of feeds was entered into the program based on the data collected for Chapter 3 (see Tables 3.1 to 3.7). Although, there were gaps (i.e. protein degradability, ADF, NDF and some minerals) in this information (see Chapter 3, Section 3.9), it represented the only published sources of data on the nutrient profiles of the feeds to be used. Where information on the chemical composition of a feed was incomplete it was obtained from the feed library of CAMDAIRY.

At the next step, the predicted (from UDDER) cow DM intake was entered into CAMDAIRY for the strategies; "average farm", "drying-off 30 days later plus maize silage in early lactation" (DO30+MSE) and "drying-off 30 days later plus maize silage in late lactation" (DO30+MSL). Test runs were then executed with the "prediction of performance and profit" module for early and late lactation strategies (i.e. DO30+MSE and DO30+MSL).

As the energy equations in both models are based on ARC (1980), it was assumed that the predictions for milk production should at least be similar for energy inputs. This was performed by calibrating the CAMDAIRY output for milk production with the UDDER output for milk production. There are, however, some differences between the models on how they consider the nutritional characteristics of feeds. In the case of UDDER, it only deals with digestibility, while CAMDAIRY includes a whole range of nutritional characteristics. The test runs performed with CAMDAIRY attempted to match the quality values used in UDDER. However, this was not always possible as the values in UDDER tended to underestimate feed quality (e.g. high quality maize silage was assumed to have 73% DM digestibility in the UDDER analysis, but if this value was transferred to CAMDAIRY maize silage was represented as having a ME content of 9 MJ/kgDM and classified as being of low to medium quality). Therefore, test runs were performed using both low and high quality (10.5 MJME/kgDM) maize silage in an attempt to overcome this inconvenience.

Subsequently, alternative diets were analysed to identify feed mixes that would produce further increases in milk production in early lactation compared to those obtained in the experiment with UDDER (see Chapter 4). The methodology followed included the combination of the same feeds used in UDDER (pasture and maize silage) plus the use of a maize silage balancer (13.5 MJME/kgDM). Maize silage balancers have been suggested as means to provide nutrients that are not at adequate levels to maximize the production of pasture-maize silage fed dairy cows (Moller and McKay 1994). Under these dietary conditions, the cows were assumed to have the same management as those for the DO30+MSE and DO30+MSL strategies, but a maximum DM intake of 16 kgDM per cow/day. Finally, an attempt to quantify the likely benefits from feeding supplements was performed using a spreadsheet that considers advantages and disadvantages of feeding supplements (Parker and Edwards 1994, Appendix 4).

5.4 Results

<u>Early lactation</u>

The model prediction of performance for cows fed 14.8 kg of pasture DM in the fourth week of lactation showed that they are capable of producing 19.9 litres of milk per day in both UDDER and CAMDAIRY (Table 5.1). The results from CAMDAIRY suggest that the amount of rumen degradable protein (RDP) in the diet was enough to produce up to 27.5 litres per cow day. However, undegradable dietary protein (UDP) would limit production to 18.8 litres per cow day. The pasture diet provided satisfactory levels of both calcium and phosphorus for milk production. In addition, the model predicts that cows would loose body condition (400 g/d) and that energy from this would be directed towards milk production.

Table 5.1. Predicted pasture dry matter intake, change in average condition score and likely milk production (litres/day) during the fourth week of lactation for different nutritional parameters for an average year on No.4 dairy farm using UDDER and CAMDAIRY.

	Cow		Nutritional parameters in diet				
	DMI[1]	ME[2]	RDP[3]	UDP[4]	Ca[5]	P[5]	ACS[6]
Model	(kgDM)		------------(Litres of milk)----------				(kg)
UDDER	14.8	19.9					
CAMDAIRY	14.8	19.9	27.5	18.8	41.5	27.2	-.4

1 = Dry matter intake kg DM, 2 = Metabolisable energy, 3 = Rumen degradable protein, 4 = Undegradable dietary protein, 5 = Calcium, 6 = Phosphorus, 7 = Change in average cow condition score (kg per day).

The prediction of performance using CAMDAIRY for cows fed 10.9 kg DM of pasture plus 4 kg DM maize silage (9.7 MJME/kgDM) in early lactation showed that the energy available would allow milk yields of 19.2 litres of milk per day (Table 5.2). The amount of RDP in the diet would be enough to produce 23.4 litres milk per cow per day, but the UDP content may limit production to 17.7 litres per cow per day. The combination of pasture and maize silage provides sufficient levels of calcium and phosphorus for the milk production achievable from the available energy. Under these feeding conditions the cows would lose 200 g/day.

On the other hand, energy intake would limit production to 19.5 litres per cow per day when cows are fed 10.9 kg pasture DM and 4 kg DM maize silage (10.5 MJME/kgDM) (Table 5.2). The amount of RDP available would support milk production of up to 23.4 litres per cow per day, and UDP up to 17.9 litres per cow per day. Calcium and phosphorus levels would not limit milk production under this feeding system. Under this feeding strategy the predicted liveweight loss is 200 g/d.

Table 5.2. Predicted dry matter intake, change in condition score and likely milk production (litres/day) during the fourth week of lactation for different nutritional parameters for strategy DO30+MSE (feeding medium and high quality maize silage in early lactation) on No.4 dairy farm using UDDER and CAMDAIRY.

	Cow	Nutritional parameters in diet					
	DMI[1]	ME[2]	RDP[3]	UDP[4]	Ca[5]	P[5]	ACS[6]
Model	(kgDM)		--------(Litres of milk)----------				(kg)
UDDER	14.9	19.2					
CAMDAIRY (Low quality MS)	14.9	19.2	23.4	17.7	34.5	24.8	-.2
CAMDAIRY (High quality MS)	14.9	19.5	23.4	17.9	34.5	24.8	-.2

1 = Dry matter intake kg DM, 2 = Metabolisable energy, 3 = Rumen degradable protein, 4 = Undegradable dietary protein, 5 = Calcium, 6 = Phosphorus, 7 = Change in average cow condition score (kg per day).

Late lactation

The prediction of performance using CAMDAIRY for cows consuming 6.5 kg DM of pasture and 4 kg DM per cow per day of maize silage (10.5 MJME/kgDM) in late lactation shows that energy intake limits production to 7.8 litres per cow per day (Table 5.3). The amount of RDP available would sustain production levels up to 10.8 litres per cow per day, although the quantity of UDP may limit milk production. Calcium and phosphorus levels are well above those recommended for maintenance and production at this stage of lactation. Under this feeding system the cows are gaining 200 g/day of liveweight. It should be noted that at this time the diet is also contributing to foetal growth.

Table 5.3. Predicted cow dry matter intake, change in condition score and likely milk production (litres/day) during the 34th week of lactation for different nutritional parameters for strategy DO30+MSL (feeding high quality maize silage in late lactation) on No.4 dairy farm using UDDER and CAMDAIRY.

	Cow	Nutritional parameters in diet					
	DMI[1]	ME[2]	RDP[3]	UDP[4]	Ca[5]	P[5]	ACS[6]
Model	(kgDM)	--------(Litres of milk)----------					(kg)
UDDER	10.5	7.8					
CAMDAIRY	10.5	7.8	10.8	7.2	19.9	14.3	.2

1 = Dry matter intake kg DM, 2 = Metabolisable energy, 3 = Rumen degradable protein, 4 = Undegradable dietary protein, 5 = Calcium, 6 = Phosphorus, 7 = Change in average cow condition score (kg per day).

<u>Alternative diets to increase milk yields</u>

The analysis diets by CAMDAIRY that could further enhance milk production per cow are presented in Table 5.4. For cows fed diet No.1 (15 kgDM pasture containing 11.8 MJME/kgDM) energy would be the limiting factor, and production would be up to 20.1 litres per cow/day. This diet has a significant protein imbalance. Cows would lose 0.1 kg daily under this feeding regimen. Cows fed diets No.2 and No.3 (see Table 5.4 for diet composition) would achieved a higher milk production response but energy remained the limiting factor for milk production. For both the No.2 and No.3 diets the amount of RDP available for milk production was reduced while the amount of UDP available for milk production was increased. Cows would not lose liveweight under these feeding conditions.

Table 5.4. Suitability of alternative diets to increase milk production of cows in early-lactation at No.4 dairy farm, based on a CAMDAIRY prediction of cow performance.

Nutritional parameter	Diet 1[a]	Diet 2[b]	Diet 3[c]
	---------------(litres per cow/day)------------------------		
Energy	20.1	21	21.1
RDP	27.1	25.8	25.9
UDP	18.6	20.2	20.7
LW change (kg)	-0.1	0	0

[a] 15 kgDM pasture of 11.8 MJME/kgDM, 24% CP, 20% UDP of total protein.
[b] 16 kgDM diet composed of 12 kgDM pasture of 11.8 MJME/kgDM, 24% CP, 20% UDP of total protein, 3 kgDM maize silage of 10.5 MJME/kgDM, 8% CP and 40% UDP of total protein and 1 kgDM maize silage balancer of 13.5 MJME/kgDM, 24% CP and 60% UDP of total protein.
[c] 16 kgDM diet composed of 11.5 kgDM pasture of 11.8 MJME/kgDM, 24% CP, 20% UDP of total protein, 3 kgDM maize silage of 10.5 MJME/kgDM, 8% CP and 40% UDP of total protein and 1.5 kgDM maize silage balancer of 13.5 MJME/kgDM, 24% CP and 60% UDP of total protein.

5.5 Discussion

A common feature amongst the pasture-based diets analysed for No.4 dairy farm was high levels of RDP. These high protein levels are one of the major causes of imbalances in pasture diets (Ulyatt and Waghorn 1993). Energy is likely to be the main limiting factor for milk output, since this is required to incorporate the high levels of RDP into microbial protein. Excess RDP will be absorbed through the rumen wall as ammonia and converted to urea in the liver (Brookes et al. 1992). This process needs a significant amount of energy and this leads to inefficient dietary energy utilization at high levels of protein intakes. Consequently, high crude protein levels may aggravate the energy deficit in the diet of pasture-based dairy cows through urea production (Moller et al. 1993). It may also negatively influence the reproductive performance of pasture-based dairy cows (Williamson and Fernandez-Baca 1992). Neither of these effects are adequately measured by CAMDAIRY.

CAMDAIRY indicates that the inclusion of maize silage in the ration of grazing dairy cows would produce a more balanced diet, as a consequence of decreased RDP intake. This should contribute to improved energy utilization (Satter et al. 1992). However, the inclusion of maize silage in the diet (Table 5.2) decreases the amount of UDP available for milk production relative to that obtained from pasture-only diets (Table 5.1). Lean (1993) suggested that feeding maize silage to grazing dairy cows without a supplementary protein source may cause cows to fatten rather than to produce milk. CAMDAIRY shows that cows fed maize silage in early lactation, as suggested for No.4 dairy farm, will lose 200 gm per day compared to 400 gm per day for cows fed pasture-only diets (Tables 5.1 and 5.2).

The use of high quality maize silage (Table 5.2) in early lactation enhanced milk production by 0.6 litres per cow per day compared to the use of low quality maize silage (Table 5.2). This effect can be directly attributed to higher energy intake.

The evaluation of maize silage use in late lactation with CAMDAIRY also suggests that at this stage of lactation an excess of RDP is also present in the diet. Thus, the assumptions in CAMDAIRY regarding the fate of crude protein (CP) intake in relation to predictions of milk yield are extremely important. Changes in CP percentage were therefore performed to evaluate the sensitivity of the model to variation in crude protein levels (Table 5.5). Assuming a CP degradability of 80%, the sensitivity analysis showed that as the CP percentage is increased so does the amount of RDP available for milk production (i.e. from 18.5 litres/cow day for pasture containing 15% CP to 29.4 litres/cow day for pasture with 30% CP). While, the UDP available for milk production also increases, milk production would be restricted to 15.1 litres/cow day for pasture containing 15% CP to 19.7 litres/cow day for pasture with 30% CP. This analysis suggests that CAMDAIRY does not penalize excess protein levels, because as the CP is increased the amount of energy available for milk production remains constant.

Table 5.5. Probable milk production responses (li/cow/day) predicted by CAMDAIRY for different levels of crude protein in pasture dry matter (DM).

Diet component	Crude protein content (%/DM)			
	15	20	25	30
Energy	19.2	19.2	19.2	19.2
RDP	18.5	23.6	27.9	29.4
UDP	15.1	16.8	18.4	19.7

As discussed above, the introduction of maize silage appeared to produce a more balanced diet, however, excess RDP and consequent inefficient energy use is still present with this diet. The introduction of maize silage "balancers" (including UDP or by-pass protein supplement) have been suggested as a means to achieve a more balanced diet (Lean 1993, Edwards and Parker 1994). The results presented in Table 5.5 suggests that this strategy may produce an "immediate response" of approximately one litre of milk per day. If it is assumed that the extra litre of milk at peak production results in a total milk response of 1.6 milk/cow per kg supplement some calculations on the likely returns to supplementation can be performed. If No.4 dairy farm is already feeding pasture and maize silage in the spring (see Chapter 4) the only variable (marginal) cost that needs to be considered here is that of the maize balancer. A spreadsheet (Appendix 4) that takes into account benefits that may be important with supplementary feeding, such as improved reproductive performance and reduced culling but not improved condition score or increases in average pasture cover, was used to analyse the results of feeding ration balancer in early lactation. This suggested a net profit per cow of $7.93 is possible (Appendix 4). It is also important to point out that the calculations presented here are based on the results of a static model; several factors can influence the milk production response of cows to supplements (see Chapter 2). Similarly the uncertainty of events such as pasture growth and pasture quality are also likely to be important determinants of the final outcome.

5.6 Conclusions

CAMDAIRY's main disadvantage for analysing the diet of pasture-based dairy cows is that it does not penalize the usually high RDP excesses in these diets. An improvement to the program would be to include equations to calculate the energy lost in eliminating excess nitrogen. It would improve the accuracy of the predictions in milk production that under the present conditions may be overestimating the milk production response.

The comparison of the output from CAMDAIRY and UDDER suggested that cows fed pasture-only diets and pasture diets supplemented with maize silage have excess RDP. The supplementation of the pasture maize silage diet with maize silage balancer decreased the quantity of RDP and improved overall milk production. This increase was achieved through a more balanced diet (i.e. increased amount of energy and decreased amount of RDP).

Despite the limitations of the computer models evaluated in this study, some general comments can be made on the opportunity for ration balancing in New Zealand dairy farm management. Ration balancing may be applied to pastoral-based systems, but it requires a good farm and animal monitoring system to be in place. This monitoring system should identify, 3-4 weeks in advance, the appropriate time period to introduce supplements in order to overcome feed deficits. In addition, relevant farmer skills to allocate the amount of pasture on offer and to monitor the total amount of pasture consumed is required to successfully implement a ration balancing program (Muller 1993b).

A parallel on-farm monitoring program for pasture quality is also essential since this provides the data necessary to identify feeds to complement the nutritional deficiencies of pasture (Parker and Edwards 1994). The same concept applies to the quality of supplements (e.g. hay, silage or industry by-products) because they will also affect the final milk production response. However for the latter group of feeds only one analysis (i.e. prior to purchase) will usually be necessary. In terms of variation on pasture quality, Near Infrared Reflectance Spectroscopy (NIRs) may offer farmers the opportunity to rapidly and inexpensively analyse feeds in order to obtain information on the chemical composition of the feeds. This information will enable the farmer or nutritional consultant, with the help of a computer program, to determine the type and quantities of supplements to be fed.

Chapter 6

Conclusions

Milk production per cow under New Zealand's pastoral conditions averages 275 kg MS/lactation (LIC 1993). While this system of milk production has low variable costs, and encourages moderate to high stocking rates, the upper potential for milk output from a pasture-only diet is limited to about 1000 kgMS/ha (Bryant 1990). Even at low stocking rates this is substantially less than the genetic potential of the New Zealand herd (Edwards and Parker 1994). Furthermore, competition from other countries, particularly Australia and those in South America with similar pasture-based milk production systems which can replicate New Zealand dairy farming systems, will become increasingly competitive in the future as their industry organisation and marketing strategies are improved (see Dairy Exporter February 1994, p2). At present, Australia is recognizing that improved animal nutrition and pasture utilisation are key factors in lowering the cost of milk production (Conroy and Monks 1994).

New Zealand dairy farmers who have captured the opportunities provided by pasture-only systems, therefore need to look to other means to profitably increase milk production. One option, well-tested in Northern Hemisphere countries, is to offer cows a consistent high quality balanced diet. This technology could be adapted to pasture-based systems (Muller 1993b). At present this option mainly applies to farmers already achieving high levels of milksolids production under pasture conditions, and hence where there is only small scope for further increases in milk production using pasture-only diets.

The objectives of this study were to: investigate the potential use of ration balancing in the context of New Zealand pastoral dairy systems, collect information on the nutritional characteristics of New Zealand feeds and use it in ration balancing programs, evaluate the effects of supplementing the diet of grazing dairy cows in early and late lactation on production per cow and dairy farm productivity using "UDDER" and finally, to study available software on ration balancing and to perform tests runs with a ration balancing model (CAMDAIRY) to study the suitability of the diets developed only on the basis of energy supply (with UDDER).

A literature review on the nutritional characteristics and quality factors of New Zealand feeds was completed. Simulations were run using UDDER for a case study dairy farm to identify opportunities to profitably increase milk production per cow through the use of supplements to extend the lactation period. Finally, test runs evaluating the diet fed to grazing dairy cows in UDDER were executed using CAMDAIRY, and alternative diets which provided a better nutritional balance were developed.

It was found that the nutritional characteristics of New Zealand pastures and green feeds are not well documented (Chapter 3). In addition, the available information generally does not account for regional variation or changes associated with pasture maturity. These two factors may strongly influence the nutritional characteristics of pasture for milk production. This lack of information presently constraints the use of ration balancing programs. The introduction of Near Infrared Reflectance Spectroscopy (NIRs) (see Dairy Exporter August 1994, p40) will help to generate a more nutritionally complete database of New Zealand pastures, green feeds and industry by-products suitable for livestock feeding. Feed evaluation centres using NIRs would offer farmers the opportunity for rapid, reliable and low cost feed analysis for a wide range of nutritive parameters such as those already in operation in the US (Linn and Martin 1991) and in the UK (Baker and Barnes 1990). In these countries farmers mail forage samples for analysis to feed evaluation centres and they receive rapid sample turnaround. Under pastoral conditions, this technology has been satisfactorily tested in Australia (Kellaway et al. 1993). The information obtained by NIRs will aid nutritional consultants in evaluating options for balancing the diet of grazing dairy cows.

The simulation model UDDER offers the opportunity to identify and analyse alternative farm management practices on pastoral dairy farms. The simulation process makes it possible to quantify the effect of management changes before they are implemented. Therefore, UDDER can be used as a tool to support decision making process. Lack of input data on pasture productivity and animal feed requirements are the main constraints to the use of UDDER (details of cow liveweights and condition score can be obtained more readily).

The UDDER analysis suggested that milk production per cow can be profitably increased through the combination of management alternatives such as extending lactation and the introduction of supplements at critical times of the year. The supplementary feeding option will largely depend on the cost of the supplement and the value of milk, although other factors such as herd reproduction and effects on risk are also important considerations in their use. In this sense, the introduction of seasonal milk pricing schemes (e.g. Bay Milk Products Newsletter December 1994 or Tui Milk Products premium milk price for off-peak milk) during the 1994/95 season should encourage farmers to extend lactations and milk longer because of higher returns for non-peak milk. However, increased lactation length requires measures to be taken to avoid negative carryover effects on the herd and other farm resources (Gray et al. 1992). These measures include the provision of enough supplements or average pasture cover to maintain an acceptable average cow condition score and an adequate level of milk production in both the current and forthcoming lactation. The implementation of these management alternatives will require careful planning of supplementary feeding (i.e. maize or pasture silage). Evaluation of these alternatives under the new seasonal milk pricing provides an opportunity for further research.

In order to overcome UDDER's nutritional limitations, CAMDAIRY a linear programming model for analysing and formulating dairy cow rations, was used to evaluate the diets "fed" to cows by UDDER. The analysis carried out with CAMDAIRY confirmed the nutritional imbalance of a pasture-only diets. It also suggested that supplementing grazing dairy cows with maize silage diets would reduce the energy-protein imbalance of pasture-only diet. Further research in this field may include an evaluation of the effects supplementing the diet of cows grazing high quality spring pasture with high quality maize silage. Satter et al. (1992), identified this forage as a reasonably priced option to balance the diet of grazing dairy cows.

CAMDAIRY is a static model that provides solutions on a daily basis. In contrast, a dairy farm system is dynamic and stochastic. Incorporating the CAMDAIRY routine at intervals throughout a run of UDDER would be useful from the viewpoint of herd feed management. The combination of static and dynamic models using the same terminology and measurement units into a single computer package may help to improve the accuracy of model predictions. At present neither of the programs consider the likely effects of improved feeding strategies on herd reproductive performance and there is very little information available on which to base possible response relationships. Future research programs should therefore include and quantify the effects of supplements on the reproductive performance of the herd as well as other carry-over effects (e.g. as McCallum et al. 1994 described for the meal feeding system trial at Waimate West demonstration farm).

The implementation of ration balancing in New Zealand dairy farm management will require a much improved definition of the seasonal and regional variation in pasture quality, in order to fully identify the deficiencies of pasture at particular periods of the year. Without this information ration balancing can only carried out by approximation and *ad hoc* reaction to milk responses to different feed mixes tried on farms. Individual farm data on pasture quality will also be necessary to cast supplements to balance the diet of pasture-based cows. Once these data are available full commercial trials may be implemented to fully evaluate ration balancing on all aspects of dairy farm productivity.

References

AGLINK. (1983). Fertilisers maintenance requirements for dairy farms. *Farm Production and Practice.* Ministry of Agriculture and Fisheries.

Agricultural Research Council (ARC) (1980). The nutrient requirements of ruminant livestock. Farnham Royal,UK: Commonwealth Agricultural Bureaux.

Allden, W. G. (1981). Energy and protein supplements for grazing livestock Pp. 289-307. *In:* Grazing Animals, F.H.W. Hurley. *ed. World Animal Science.* Amsterdam: Elsevier.

Ball, P. R., Brougham, R. W., Brock, J. L., Crush, J. R., Hoglund, J. H. and Carran, R.A. (1979). Nitrogen fixation in pasture 1. Introduction and general methods. *New Zealand Journal of Experimental Agriculture* **7**: 1-5.

Barry, T. N. (1975). Effect of treatment with formaldehyde, formic acid, and formaldehyde-acid mixtures on the chemical composition and nutritive value of silage. 1. Silages made from immature pasture compared with hay. *New Zealand Journal of Agricultural Research* **18**: 285-294.

Baker, C.W. and Barnes, R. (1990). The application of near-infrared spectometry to forage evaluation in the agricultural development and advisory service. Pp. 337-351. *In:* Feedstuff evaluation, Wiseman, J. and Cole, D.J. *eds.* London, Butterworths.

Bramwell, N. F., Parker, W. J., Gray, D. I. and McCutcheon, S.N. (1993). The potential of industry by-products as supplementary feeds for dairy cows in the Hawkes Bay region. *Proceedings of the New Zealand Society of Animal Production* **53**: 55-59.

Brookes, I.M. and Holmes, C.W. (1988). The assessment of pasture utilisation on dairy farms. *Proceedings of the New Zealand Grassland Association,* **49:** 123-126.

Brookes, I. M. (1993). The effects on milk production of supplementing pasture-fed dairy cows. Pp 83-93. *In:* Improving the Quality and Intake of Pasture-Based diets for Lactating Dairy Cows. Edwards, N.J.; Parker, W.J *eds Occasional Publication No.1,* Department of Agricultural and Horticultural Systems of Management. Massey University.

Brookes, I. M., Barry, T. N. and Moughan, P. J. (1992). Nutrition and feeding of livestock. Study guide No.2. Department of Animal Science. Massey University.

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

Broster, W. H. and Thomas, C. (1981). The influence of level and pattern of concentrate input on milk output. Pp. 49-69. *In:* Recent Advances in Animal Nutrition, W.Haresign *ed.* London: Butterworths.

Bryant, A. M. (1993). Dairy production in New Zealand: Where we should be going and why. *Dairyfarming Annual Massey University,* **45:** 1-5.

Bryant, A. M. (1983). Does nitrogen fertiliser have a place in dairying. *Proceedings of the Ruakura Farmers Conference,* **35:** 121-124.

Bryant, A. M. (1984). Feed and management strategies at Ruakura. *Proceedings of the Ruakura Farmers Conference,* **36:** 20-24.

Bryant, A. M. (1990). Present and future grazing systems. *Proceeding of the New Zealand Society of Animal Production,* **50:** 35-38.

Bryant, A. M., Carruthers, V. R. and Trigg, T. E. (1983). Nutritive value of pressed herbage residues for lactating dairy cows. *New Zealand Journal of Agricultural Research,* **26:** 79-84.

Bryant, A. M. and Trigg, T. E. (1982). The nutrition of the grazing dairy cow during early lactation. Pp. 185-207. *In:* Proceedings of the Conference on Dairy Production from Pasture, Macmillan, K.L. and Taufa V.K. *eds.* New Zealand and Australian Societies of Animal Production.

Butler, W. R. and Smith, R. D. (1987). Interrelationships between energy balance and postpartum reproductive function in dairy cattle. *Journal of Dairy Science,* **72:** 767-783.

Buxton, D. R. and Fales, S. L. (1994). Plant environment and quality. Pp. 155-199. *In:* Forage Quality, Evaluation, and Utilization. Fahey G.C. *ed.*

Madison, Wisconsin, USA: American Society of Agronomy, Inc; Crop Science Society of America, Inc; Soil Science Society of America, Inc.

Cameron, K. C. (1993). The use of nitrogen fertilisers on dairy farms. *Dairyfarming Annual Massey University,* **45:** 50-57.

Church, D. C. and Pond, W. G. (1988). Basic animal nutrition and feeding. New York: John Wiley & Sons.

Clark, D. A. (1993). Silage for milk production. *Proceeding of the Ruakura Farmers Conference,* **45:** 41-46.

Conroy, F. and Monks, L.A. Dairying - Technology plays key role in changing times. *Agricultural Science.* November 1994. Pp. 40-46.

Cowan, R. T. (1985). Pasture and supplements in the tropics and subtropics. Pp. 109-117. *In:* The Challenge: Efficient dairy production. Phillips, T.E. *ed.* Albury-Wodonga, Australia, Australian Society of Animal Production.

Cowan, R. T., Davison, T. M. and O'Grady, P. (1977). Influence of level of concentrate feeding on milk production and pasture utilisation by Friesian cows grazing tropical grass-legume pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry,* **17:** 373-379.

CSIRO. Australian Agricultural Council. Ruminants Subcommittee (1990). Feeding Standards for Australian Livestock. Ruminants. Melbourne: Standing Committee on Agricultural Ruminants.

Davison, T. M., Marschke, R. J. and Brown, G. W. (1982). Milk yields from feeding maize silage and meat-and-bone meal to Friesian cows grazing a tropical grass and legume pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry,* **22:** 147-154.

Deane, T. (1993). The relationship between milksolids production per hectare and economic farm surplus on New Zealand dairy farms. *Proceedings of the New Zealand Society of Animal Production,* **53:** 51-53.

De Visser, H. and Steg, A. (1988). Utilization of by-products for dairy cow feeds. Pp. 378-394. *In:* Nutrition and Lactation in the Dairy Cow, Garnsworthy, P.C. *ed.* London U.K, Butterworths.

Le Du, Y. L. P and Newberry, R.D. (1981). Supplementing the grazing dairy cow during period of pasture restriction. *Grass and Forage Science,* **36:** 173-174.

Edwards, N. J. and Parker, W.J. (1994). Increasing per cow milksolids production in a pasture-based dairy system by manipulating the diet: A review. *Proceedings of the New Zealand Society of Animal Production,* **54:** 267-273.

Edwards, N. J., Parker, W. J. and Muller, L. D. (1994). Strategic ration balancing of a pasture-based diet. Proceedings of a 3 day seminar provided for the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association. : Faculty of Veterinary Science, Massey University.

Elrod, C. D. and Butler, W. R. (1993). Reduction of fertility and alteration of uterine pH in heifers fed excess ruminally degradable protein. *Journal of Animal Science,* **71:** 694-701.

Farm Facts Seasonal Notes for Dairy Farmers No.3. (1993). Feed values of New Zealand forages. Livestock Improvement Corporation.

Frame, J. (1992). Silage making. *Improved Grassland Management.* Farming Press Books UK.

Geenty, K. G. and Rattray, P. V. (1987). The energy requirements of grazing sheep and cattle. Pp. 39-53. *In:* Livestock Feeding on Pasture, Nicol, A.M. *ed.* *Occasional Publication No.10.* New Zealand Society of Animal Production.

Gleeson, P. A. (1981). Concentrate supplementation for spring calving cows. *Grass and Forage Science,* **36:** 138-139.

Gordon, F. J. (1989). The principles of making and storing high quality, high intake silage. Pp. 3-19. *In:* Silage for Milk Production, Mayne, C.S. *ed.* *Occasional Symposium No.23.* British Grassland Society.

Grainger, C. (1991). Limitations to using supplements in pasture based dairy. Pp. 13-18. *In:* Dairying and Feed Supplements. How do they fit together?, Donohue, G. *ed.* Australian Society of Animal Production.

Grainger, C. and Mathews, G.L. (1989). Positive relation between substitution rate and pasture allowance for cows receiving concentrates. *Australian Journal of Experimental Agriculture,* **29:** 355-360.

Grainger, C. and McGowan, A. A. (1982). The significance of pre-calving nutrition of the dairy cow. Pp. 134-171. *In:* Proceedings of the Conference on Dairy Production from Pasture, Macmillan, K.L. and Taufa V.K. *eds*. New Zealand and Australian Societies of Animal Production.

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

Gray, D. I., Lynch, G. A., Lockhart, J. C., Parker, W. J., Todd, E. G. and Brookes, I. M. (1992). A conceptual framework for an expert system to improve drying off decisions on seasonal supply dairy farms. *Proceedings of the New Zealand Society of Animal Production,* **52:** 11-12.

Haresign, W. (1979). Body condition, milk yield and reproduction in cattle. Pp. 107-122 *In:* Recent Advances in Animal Nutrition, W.Haresign *ed.* London: Butterworths.

Harris, P.M. and Douglas, J.A. (1981). Chemical composition of New Zealand feed grains. Joint DSIR-MAF internal report.

Hodgson, J. (1990). Grazing Management, Science into Practice. Longman Scientific and Technical. Essex, England.

Hoffman, K., Muller, L. D., Fales, S. L. and Holden, L. A. (1993). Quality evaluation and concentrate supplementation of rotational pasture grazed by lactating cows. *Journal of Dairy Science,* **76:** 2651-2663.

Holmes, C. W. (1987). Pastures for dairy cows. Pp. 133-143. *In:* Livestock Feeding on Pasture, Nicol, A.M. *ed. Occasional Publication No.10.* New Zealand Society of Animal Production.

Holmes, C. W. (1990). Principles and practices of profitable dairy farming. *Proceedings of the Ruakura Farmers Conference,* **42:** 60-67.

Holmes, C. W., Edwards, N. J. and Parker, W. J. (1994). The use of supplementary feeding to extent lactation. *Dairyfarming Annual Massey University,* **46:** 191-193.

Holmes, C. W. and Hughes, T. P. (1993). New Zealand dairy farming in 2010 - Implications for nutrition of dairy cattle. Pp. 1-10. *In:* Improving the Quality and Intake of Pasture-Based diets for Lactating Dairy Cows. Edwards, N.J.; Parker, W.J *eds. Occasional Publication No.1,* Department of Agricultural and Horticultural Systems of Management. Massey University.

Holmes, C. W. and Macmillan, K. L. (1982). Nutritional management of the dairy herd grazing on pasture. Pp. 244-274. *In:* Proceedings of the Conference on Dairy Production from Pasture, Macmillan, K.L. and Taufa V.K. *eds.* New Zealand and Australian Societies of Animal Production.

Holmes, C. W. and Wilson, G. F. (1987). Milk production from pastures. Wellington, New Zealand: Butterworths Agricultural Books.

Holmes, C.W and Wheeler J.S. (1973). The use of nitrogenous fertiliser on the seasonal supply dairy farm, No.3 dairy unit, Massey University (1971-73). *Dairyfarming Annual Massey University,* **25:** 45-54.

Hughes, T. P. (1984). Definition and objectives of reproduction in dairy cows. Pp. 3-9. *In:* Dairy Cattle Reproduction, Barrel, G.K. *ed.* Animal Industries Workshop. Lincoln College, New Zealand.

Hulme, D. J., Kellaway, R. C., Booth, P. J. and Bennett, L. (1986). The camdairy model for formulating and analysing dairy cow rations. *Agricultural Systems,* **22:** 81-108.

Hutton, J. B. and Douglas, J. A. (1975). Growing and using maize on the dairy farm. *Proceedings of the Ruakura Farmers Conference,* **27:** 76-82.

Irwin, C. and Kellaway, R.C.(1991). CAMDAIRY: Nutritional management system for dairy cattle - *User Manual.* University of Sydney. Australia.

James, K. A. C., Treloar, B. P., McEwan, J. M., Patchel, M.R. and Smith, W. C. (1987). Nutritional evaluation of two New Zealand cultivars of triticale ("Aranui" and "Karere") using the rat, pig and cockerel. *New Zealand Journal of Agricultural Research,* **30:** 159-168.

John, A. and Lancashire, J. A. (1981). Aspects of the feeding and nutritive value of Lotus species. *Proceedings New Zealand Grassland Association,* **41:** 152-159.

Joyce, J. P., Brunswick, L. and Parker, J. (1972). Feeding value of lucerne. *Proceedings of the New Zealand Society of Animal Production,* **32:** 54-63.

Kellaway, R.C. (1992). Nutrient intake by grazing dairy cows. *Proceedings of the Australian Cooperative Foods Country Tour.* University of Sydney. Pp. 24-30.

Kellaway, R.C. and Porta, S. (1993). Feeding concentrates: Supplements for dairy cows. Glen Iris, Victoria, Australia: Dairy Research and Development Corporation.

Kellaway, R.C., Stimson, C. and Tassel, R.C. (1993). Near-infrared spectroscopy analysis of the nutrient content of dairy pastures. Pp 599-600. *In:* Proceedings of the XVII International Grassland Congress, Palmerston North, New Zealand.

King, K. R., Stockdale, C.R and Trigg, T.E. (1990). Influence of high energy supplements containing fatty acids on the productivity of pasture-fed dairy cows. *Australian Journal of Experimental Agriculture,* **30:** 11-15.

Lancashire, J. A. and Ulyatt, M. J. (1974). Liveweight gains by sheep grazing Browntop and Perennial Ryegrass. *Proceedings of New Zealand Grassland Association,* **35:** 110-117.

Lara, P. (1993). Multiple objective fractional programming and livestock ration formulation: A case study for dairy cow diets in Spain. *Agricultural Systems,* **41:** 321-334.

Larcombe, M. (1990a). UDDER: A desktop dairy farm for extension and research. Operating manual.

Larcombe, M. (1990b). UDDER: A Desktop Dairyfarm for Extension and Research. *Dairy Cattle Society of the New Zealand Veterinary Association.* Proceedings of the Society's 7th Seminar. 151-152.

Lean, I. J. (1991). Fertility and nutrition. *Dairy Medicine and Production.* Post-Graduate Committee in Veterinary Science. University of Sydney. Pp. 217-239.

Lean, I. (1987). Nutrition of Dairy Cattle. The University of Sydney. Post-Graduate Foundation in Veterinary Science. Sydney, Australia.

Lean, I. (1993). Supplementary feeding: New Opportunities. *In: Dairy Production, Making Dollars out of Genes.* NRM New Zealand Limited. Pp. 17-21.

Leaver, J. D. (1985b). Effects of supplements on herbage intake and performance. Pp. 79-88. *In:* Grazing, Frame, J. *ed. Occasional Publication No.19.* British Grassland Society.

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

Leng, R. A. and Nolan, J. V. (1984). Nitrogen metabolism in the rumen. *Journal of Dairy Science,* **67:** 1072-1087.

Linn, J. G. and Martin, N. P. (1991). Forage quality analyses and interpretation. *In: Dairy Nutrition Management.* **7:** 509-523. The Veterinary Clinics of North America: Food Animal Practice.

LIC (Livestock Improvement Corporation). (1993.). Annual Report.

Livestock Improvement Corporation. (1994). Dairy Statistics 1993/94.

Mackle, T. R. and Bryant, A. M. (1994). How good is pasture? *Proceedings of the Ruakura Farmers Conference,* **46:** 64-69.

Macmillan, K. L. (1984a). Calving patterns and their effects on milk production. *Proceedings of the Ruakura Farmers Conference,* **36:** 25-28.

Macmillan, K. L. (1984b). Factors affecting reproductive performance in dairy cows. Pp. 25-30. *In:* Dairy Cattle Reproduction, Barrel, G.K. *ed.* Animal Industries Workshop. Lincoln College, New Zealand.

Macmillan, K. L., Henry, R. I., Taufa, V. K. and Phillips, P. (1990). Calving patterns in seasonal dairy herds. *New Zealand Veterinary Journal,* **38:** 151-155.

Mayne, C. S. (1990). Effects of supplementation on the performance of both growing and lactating cattle at pasture. Pp. 55-71. *In:* Management issues for the grassland farmer in the 1990's, Mayne, C.S. *ed. Occasional Symposium No.25,* British Grassland Society.

McCallum, D., Thomson, N. and Clough, J. (1994). Meal feeding at high stocking rates at Waitame West demonstration farm. *Dairyfarming Annual Massey University,* **46:** 50-54.

McDonald, P., Edwards, R. A. and Greenhalgh, J. F. D. (1988). Animal Nutrition. Harlow, Essex, England: Longman. 89.

McDougall, S. (1993). Stocking rate, breed, condition score and anoestrum. *Proceedings of the Ruakura Farmers Conference,* **45:** 51-56.

McKay, B. (1994). The field use of UDDER: A Desktop Dairyfarm for Extension and Research. *Dairy Cattle Society of the New Zealand Veterinary Association.* Proceedings of the Society's 11th Seminar. 124-130.

Meijs, J. A. C. (1985). Comparison of starchy and fibrous concentrates for grazing dairy cows. Pp. 129-137 *In:* Grazing, Frame, J. *ed. Occasional Publication No.19,* British Grassland Society.

Meijs, J. A. C and Hoekstra, J.A. (1984). Concentrate supplementation of grazing dairy cows. 1. Effect of concentrate intake and herbage allowance on herbage intake. *Grass and Forage Science,* **39:** 59-66.

Minson, D. J. (1982). Effects of chemical and physical of herbage upon intake. Pp. 167-182. *In:* Nutritional Limits to Animal Production from Pastures, Hacker, J.B. *ed. Proceedings of an international symposium held at St Lucia, Queensland, Australia.* Farnham Royal, UK: Commonwealth Agricultural Bureaux.

Moller, S., Matthew, C. and Wilson, G. F. (1993). Pasture protein and soluble carbohydrate levels in spring dairy pasture and associations with cow performance. *Proceedings of the New Zealand Society of Animal Production,* **53:** 83-86.

Moller, S. and McKay B. (1994). Supplementation of dairy cows fed pasture and maize silage with a ration "balancer". *Dairyfarming Annual Massey University,* **46:** 39-43.

Moran, J. B. and Stockdale, C. R. (1992). Maize silage for the pasture-fed dairy cow 1. Effect of level of silage feeding, and responses to cottonseed meal while grazing perennial pastures in the spring. *Australian Journal of Experimental Agriculture,* **32:** 279-285.

Morrison, J. (1987). Effects of nitrogen fertiliser. Pp. 61-70. *In:* Ecosystems of the World, Snaydon, R.W. *ed. 17B Managed Grasslands Analytical Studies.* Amsterdam: Elsevier.

Muller, L. D. (1992). Feeding Management Strategies. Pp. 326- 335. *In:* Large Dairy Herd Management. Van Horn, H.H. and Wilcox, C.J. *eds.* Gainsville, Florida: University of Florida.

Muller, L. D. and Holden, L. A. (July-August 1994.). Intensive rotational grazing: What are the special nutritional needs?. *Large Animal Veterinarian:* 27-29.

Muller, L. D. (1993a). Limitations of pastures for high production by dairy cows - A US perspective. Pp. 33-57. *In:* Improving the Quality and Intake of Pasture-Based diets for Lactating Dairy Cows. Edwards, N.J.; Parker, W.J *eds. Occasional Publication No.1,* Department of Agricultural and Horticultural Systems of Management. Massey University.

Muller, L. D. (1993b). Nutritional supplementation and ration balancing for high producing cows. Pp. 71-81. *In:* Improving the Quality and Intake of Pasture-Based diets for Lactating Dairy Cows. Edwards, N.J.; Parker, W.J *eds. Occasional Publication No.1,* Department of Agricultural and Horticultural Systems of Management. Massey University.

Murphy, M. (1993). An international perspective of dairying in New Zealand. Pp 1585-1586. *In:* Proceedings of the XVII International Grassland Congress, Palmerston North, New Zealand.

New Zealand Dairy Board. (1993). Annual Report 1993.

New Zealand Dairy Board. (1994). Annual Report 1994.

O'Connor, M. B., Edmeades, D. C. and Feyter, C. (1984). Making the best decisions on fertilisers and lime for dairy farms. *Proceedings of the Ruakura Farmers Conference,* **36:** 1-4.

O'Connor, M. B., Ledgard, S. F. and Feyter, C. (1989). Using nitrogen fertiliser effectively in intensive dairying systems. *Proceedings of the Ruakura Farmers Conference,* **41:** 19-22.

O'Connor, M. B., Pearce, M. G., Gravett, I. M. and Towers, N.R. (1987). Fertilising with magnesium to prevent hypomagnesemia (grass staggers) in dairy cows. *Proceedings of the Ruakura Farmers Conference,* **39:** 47-49.

O'Sullivan, M. (1984). Some aspects of pasture utilization by the grazing animal. *Journal of Irish Grassland and Animal Production,* 104-128.

Owen, J. B. (1983). Cattle feeding. Letchworth, UK: Farming Press Ltd.

Parker, W. J. and Muller, L.D. (1992). Dairy farming in Pennsylvania. Lessons for New Zealand. *Dairyfarming Annual Massey University,* **44:** 142-148.

Parker, W.J. and Edwards, N.J. (1994). Valuing supplementary feeding in a pasture-based dairy system. *Dairyfarming Annual Massey University,* **46:** 29-38.

Paterson, J. A., Belyea, R. L., Bowman, J. P., Kerley, M. S. and Williams, J. E. (1994). The impact of forage quality and supplementation regimen on ruminant animal intake and performance. Pp. 59-114. *In:* Forage Quality, Evaluation, and Utilization. Fahey, G.C. *ed.* Madison, Wisconsin, USA: American Society of Agronomy, Inc; Crop Science Society of America, Inc; Soil Science Society of America, Inc.

Peterson, R. (1988). Comparison of Canadian and New Zealand sires in New Zealand for production, weight, and conformation traits. *Research Bulletin No.5,* Livestock Improvement Corporation Limited. Hamilton, New Zealand.

Phillips, C. J. C and Leaver, J.D. (1985a). Supplementary feeding of forage to grazing dairy cows. 1.Offering hay to dairy cows at high and low stocking rates. *Grass and Forage Science,* **40:** 183-192.

Phillips, C. J. C and Leaver, J.D. (1985). Supplementary feeding of forage to grazing dairy cows. 2. Offering grass silage in early and late season. *Grass and Forage Science,* **40:** 193-199.

Phillips, C. J. C. (1988). The use of conserved forage as a supplement for grazing dairy cows. *Grass and Forage Science,* **43:** 215-230.

Phillips, T. I. (1994). Recent developments in profitable feeding of cows in Victoria. *Dairyfarming Annual Massey University,* **46:** 65-68.

Preston, T. R. and Leng, R. A. (1987). Matching ruminant production systems with available resources in the tropics and sub-tropics. Armidale: Panambul Books.

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

Ridler, B.J. and Hurley, E.M. (1984). The management policy for Massey University's large herd. *Proceedings of the Ruakura Farmers Conference,* **36:** 15-19.

Rogers, G. L. (1985). Pasture and supplements in the temperate zones. Pp. 85-108. *In:* The Challenge: Efficient dairy production. Phillips, T.E. *ed.* Albury-Wodonga, Australia, Australian Society of Animal Production.

Rogers, G. L., Robinson, I. B. and Moate, P. (1983). The supplementation of dairy cows at pasture in Victoria. Recent Developments in Animal Nutrition in Australia, University of New England: 81-89.

Rotz, C. A. and Muck, R. E. (1994). Changes in forage quality during harvest and storage. Pp. 828-868. *In:* Forage Quality, Evaluation, and Utilization. Fahey, G.C. *ed.* Madison, Wisconsin, USA: American Society of Agronomy, Inc; Crop Science Society of America, Inc; Soil Science Society of America, Inc.

Satter, L. D., Dhiman, T.R. and Cadorniga, C. (1992). Supplementation of forage and pasture for cows. *Proceedings of the Australian Cooperative Foods Country Tour.* University of Sydney. Pp. 1-15.

Shenk, J. S. and Westerhaus, M. O. (1994). The application of Near Infrared Reflectance Spectroscopy (NIRS) to forage analysis. Pp. 406-449. *In:* Forage Quality, Evaluation, and Utilization. Fahey, G.C. *ed.* Madison, Wisconsin, USA: American Society of Agronomy, Inc; Crop Science Society of America, Inc; Soil Science Society of America, Inc.

Stockdale, C. R. and Trigg, T.E. (1989). Effect of pasture feeding levels on the responses of lactating dairy cows to high energy supplements. *Australian Journal of Experimental Agriculture*, **29:** 605-611.

Stockdale, C. R. (1991). Feed supplements for dairy cows. Pp. 1-11. *In:* Dairying and Feed Supplements. How do they fit together?, Donohue, G. *ed.* Australian Society of Animal Production.

Stockdale, C. R. and Callaghan, A. a. Trigg,T.E. (1987). Feeding high energy supplements to pasture-fed dairy. Effects of stage of lactation and level of supplement. *Australian Journal of Agricultural Research,* **38:** 927-940.

Stockdale, C. R., Currie, R. and Trigg, T. E. (1990). Effects of pasture and supplement quality on the responses of lactating dairy cows to high energy supplements. *Australian Journal of Experimental Agriculture,* **30:** 43-50.

Taylor, W. a. Leaver, J.D. (1984a). Systems of concentrate allocation for dairy cattle. 1. A comparison of three patterns of concentrate allocation for autumn-calving cows and heifers offered grass silage ad libitum. *Animal Production,* **39:** 315-324.

Taylor, W. and Leaver, J. D. (1984). Systems of concentrate allocation for dairy cattle. 2. A comparison of two patterns of concentrate allocation for autumn-calving cows offered two qualities of grass silage ad libitum. *Animal Production,* **39:** 325-333.

Thomas, C. and Thomas, P. C. (1989). Response to supplementary feeding. Pp. 49-60. *In:* Silage for Milk Production, Mayne, C.S. *ed. Occasional Symposium No.23,* British Grassland Society.

Thomas, G. W. and Mathews, G.L. (1991). Comparison of two management systems of dairy farmlets based on conservation of either hay or silage. *Australian Journal of Experimental Agriculture,* **31:** 195-203.

Thomson, D. A., McCallum, D. A. and Judd, T. G. (1993). A review of grazing studies in Taranaki evaluating phosphate fertiliser and dairy production. *Dairyfarming Annual Massey University,* **45:** 57-62.

Thomson, N. A. (1982). Lime and dairy production. *Proceedings of the New Zealand Grassland Association,* **43:** 93-103.

Thomson, N. A., Roberts, A. H. C., Judd, T. G. and Clough, J. S. (1991). Maximising dairy production by using nitrogen fertiliser and calving early. *Proceedings of the New Zealand Grassland Association,* **53:** 85-93.

Ulyatt, M. J. (1981). The feeding value of herbage: Can it be improved. *New Zealand Agricultural Science,* **15:** 200-205.

Ulyatt, M. J. (1981). The feeding value of temperate pastures. Pp. 125-141. *In:* Grazing Animals, F.H.W. Hurley. *ed. World Animal Science.* Amsterdam: Elsevier.

Ulyatt, M. J., Betteridge, K., Costall, D., Knapp, J. and Baldwin, R. L. (1991). Methane production by New Zealand ruminants. A report for the ministry of DSIR GRASSLANDS.

Ulyatt, M. J., Fennessy, P. F., Rattray, P. V. and Jagush, K.T. (1980). The nutritive value of supplements. Pp. 157-184. *In:* Supplementary Feeding. A Guide to the Production and Feeding of Supplements for Sheep and Cattle in New Zealand. Drew, K.R. and Fennessy, P.F. *eds. Occasional Publication No.7,* New Zealand Society of Animal Production.

Ulyatt, M. J. and Waghorn, G. C. (1993). Limitations to high levels of dairy production from New Zealand pastures. Pp. 11-32. *In:* Improving the Quality and Intake of Pasture-Based diets for Lactating Dairy Cows. Edwards, N.J.; Parker, W.J *eds Occasional Publication No.1,* Department of Agricultural and Horticultural Systems of Management. Massey University.

Van Soest, P. J. (1982). Nutritional Ecology of the Ruminant. Portland, Oregon: Durham and Downey Inc.

VandeHaar, M. J. and Black, R. J. Ration formulation using linear programming. *In: Dairy Nutrition Management.* **7:** 541-556. The Veterinary Clinics of North America: Food Animal Practice.

Varela-Alvarez, H. (1988). Diet formulation. Pp. 371-386. *In: Basic Animal Nutrition and Feeding.* D.C. Church, and W.G. Pond, New York: John Wiley & Sons.

Waghorn, G. C. and Barry, T. N. (1987). Pasture as a nutrient source. Pp. 21-37. *In:* Livestock Feeding on Pasture, Nicol, A.M. *ed. Occasional Publication No.10,* New Zealand Society of Animal Production.

Wilkins, T. M. (1993). The viability of feedlot dairy farming in the Hawke's Bay. Unpublished research report for a special topic in real state. Department of Agricultuaral and Horticultural Systems of Management. Massey University

Williamson, N. A. and Fernandez-Baca E. (1992). The role of dietary protein and energy in dairy herd fertility. Proceedings of the 1st International Conference for the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association. Noumea.

Wilson, G. F. (1978). Average "Feeding values" of common feeds for cattle. Town Milk Industry Factsheet. Dairy Husbandry Department, Massey University.

Wilson, G. F. (1981). The magnesium status of grazing dairy cows. *Proceedings of the New Zealand Society of Animal Production,* **41:** 53.

Wilson, G. F. and Davey, A. W. F. (1982). The nutrition of the grazing cow: mid and late lactation. Pp. 219-235. *In:* Proceedings of the Conference on Dairy Production from Pasture, Macmillan, K.L. and Taufa V.K. *eds.* New Zealand and Australian Societies of Animal Production.

Wilson, G. F. and Moller, S. (1993). Imbalances in New Zealand pastures for dairy cows. Pp. 59-70. *In:* Improving the Quality and Intake of Pasture-Based diets for Lactating Dairy Cows. Edwards, N.J.; Parker, W.J *eds Occasional Publication No.1,* Department of Agricultural and Horticultural Systems of Management. Massey University.

Appendix 1: "Average farm"

Date	No.Cows	P.Growth kg DM/ha/	APC kg DM/ha	Pasture Intake kgDM/cow	MAIZE Intake kgDM/cow	MF/cow (kg)	C.S.
01.07	0	19	1675	0	0	0	0
11.07	0	20	1777	0	0	0	0
21.07	0	22	1887	0	0	0	0
01.08	54	26	2030	13.9	0	0.59	4.8
11.08	122	30	2105	14.3	0	0.74	4.8
21.08	168	33	2142	14.6	0	0.85	4.8
01.09	193	43	2167	14.8	0	0.91	4.7
11.09	202	44	2245	15	0	0.95	4.7
21.09	222	48	2325	15.2	0	0.94	4.6
01.10	226	53	2418	15.2	0	0.95	4.6
11.10	224	56	2485	15.3	0	0.93	4.5
21.10	230	55	2653	15.2	0	0.89	4.5
01.11	230	47	2642	15.2	0	0.86	4.5
11.11	230	46	2552	15	0	0.82	4.4
21.11	230	43	2453	14.8	0	0.82	4.4
01.12	230	38	2233	14	0	0.8	4.4
11.12	230	34	2171	13.9	0	0.79	4.4
21.12	230	28	2071	12.7	0	0.75	4.3
01.01	230	22	1938	10.8	0	0.68	4.1
11.01	230	17	1808	7.2	3	0.62	4
21.01	230	16	1732	4.7	3	0.5	3.7
01.02	226	16	1722	5.1	3	0.46	3.6
11.02	212	17	1708	3.9	3	0.54	3.6
21.02	197	17	1736	3.8	3	0.54	3.7
01.03	197	21	1771	4.8	0	0.5	3.7
11.03	179	22	1824	5.2	0	0.5	3.7
21.03	148	23	1874	5.6	0	0.5	3.7
01.04	129	24	1937	7.4	0	0.5	3.8
11.04	122	25	1975	11.2	0	0.49	3.8
21.04	115	26	1954	8.7	0	0.43	3.7
01.05	0	27	1980	0	0	0	0
11.05	0	29	2108	0	0	0	0
21.05	0	29	2254	0	0	0	0
01.06	0	29	2417	0	0	0	0
11.06	0	27	2635	0	0	0	0
21.06	0	19	2837	0	0	0	0

Farm size	90	Milk Income ($)	213118
Herd size	235	Concentrates ($)	0
Litres	821610	Fodder ($)	11229
Fat	38057	Nitrogen ($)	8520
Protein	30235	Agistment ($)	6826
Pasture used (t DM/ha	8.4	Crop 1 ($)	1800
Concentrates fed	0	Crop 2 ($)	0
Pasture silage fed	63.5	Total income ($)	184743
Maize silage fed	32.4	Cow costs ($)	82250
Nitrogen	8.5	Gross Margin ($)	102493
Conserved	23.7	Gross Margin ha($)	436
Crop 1	60	Gross Margin cow($)	1139
Crop 2	0		

Appendix 2: Drying-off 30 days later

Date	No.cows	P.Growth kg DM/ha/	APC kg DM/ha	Pasture Intake kgDM/co	MAIZE Intake kgDM/co	MF/cow	C.S.
01.07	0	19	1675	0	0	0	0
11.07	0	20	1777	0	0	0	0
21.07	0	22	1887	0	0	0	0
01.08	54	26	2030	13.9	0	0.59	4.8
11.08	122	30	2105	14.3	0	0.74	4.8
21.08	168	33	2142	14.6	0	0.85	4.8
01.09	193	43	2167	14.8	0	0.91	4.7
11.09	202	44	2245	15	0	0.95	4.7
21.09	222	48	2325	15.2	0	0.94	4.6
01.10	226	53	2418	15.2	0	0.95	4.6
11.10	224	56	2485	15.3	0	0.93	4.5
21.10	230	55	2653	15.2	0	0.89	4.5
01.11	230	47	2642	15.2	0	0.86	4.5
11.11	230	46	2552	15	0	0.82	4.4
21.11	230	43	2453	14.8	0	0.82	4.4
01.12	230	38	2233	14	0	0.8	4.4
11.12	230	34	2171	13.9	0	0.79	4.4
21.12	230	28	2071	12.7	0	0.75	4.3
01.01	230	22	1938	10.8	0	0.68	4.1
11.01	230	17	1808	7.2	3	0.62	4
21.01	230	16	1732	4.7	3	0.5	3.7
01.02	226	16	1722	5.1	3	0.46	3.6
11.02	212	17	1708	3.9	3	0.54	3.6
21.02	197	17	1736	3.8	3	0.54	3.7
01.03	197	21	1771	4.8	0	0.5	3.7
11.03	197	22	1824	5.1	0	0.5	3.7
21.03	186	23	1878	5.5	0	0.49	3.8
01.04	186	24	1952	9.7	0	0.48	3.8
11.04	167	24	1925	10.9	0	0.47	3.8
21.04	148	26	1881	8.5	0	0.42	3.7
01.05	129	27	1905	9.6	0	0.43	3.7
11.05	122	29	1943	10.3	0	0.43	3.7
21.05	115	29	1994	10	0	0.42	3.8
01.06	0	29	2065	0	0	0	0
11.06	0	27	2285	0	0	0	0
21.06	0	21	2493	0	0	0	0

Farm size	90	Milk Income ($)	226770
Herd size	235	Concentrates ($)	0
Litres	864586	Fodder ($)	9711
Fat	40495	Nitrogen ($)	8520
Protein	31964	Agistment ($)	6826
Pasture used (t DM/h	8.6	Crop 1 ($)	1800
Concentrates fed	0	Crop 2 ($)	0
Pasture silage fed	48.4	IOFC ($)	199914
Maize silage fed	32.4	Cow costs ($)	82250
Nitrogen	8.5	Gross Margin ($)	117664
Conserved	23.7	Gross Margin ha($)	1307
Crop 1	60	Gross Margin cow($)	501
Crop 2	0		

Appendix 3: Drying-off 30 days later plus maize silage in early lactation

Date	Number	Growth kg DM/ha/	Cover kg DM/ha	Pasture Intake (kgDM/cow	MAIZE Intake (kgDM/co	Fat	B.C.S.
01.07	0	19	1675	0	0	0	0
11.07	0	20	1777	0	0	0	0
21.07	0	22	1887	0	0	0	0
01.08	54	26	2030	13.9	0	0.59	4.8
11.08	122	30	2105	10.3	4	0.71	4.8
21.08	168	33	2198	10.6	4	0.82	4.8
01.09	193	43	2307	10.9	4	0.88	4.7
11.09	202	44	2471	11	4	0.92	4.6
21.09	222	48	2641	11.2	4	0.91	4.6
01.10	226	53	2831	15.3	0	0.95	4.6
11.10	224	56	2896	15.3	0	0.93	4.5
21.10	230	55	3055	15.3	0	0.89	4.5
01.11	230	47	3043	15.2	0	0.85	4.5
11.11	230	46	2952	15.1	0	0.81	4.4
21.11	230	43	2849	14.9	0	0.81	4.4
01.12	230	40	2563	14.6	0	0.81	4.4
11.12	230	37	2499	14.4	0	0.8	4.4
21.12	230	31	2414	13.6	0	0.78	4.4
01.01	230	25	2282	13.2	0	0.75	4.4
11.01	230	21	2112	9.4	3	0.7	4.3
21.01	230	20	2010	7.1	3	0.62	4.1
01.02	226	19	1963	7.5	3	0.59	4
11.02	212	19	1907	4.1	3	0.61	4.1
21.02	197	20	1956	3.9	3	0.6	4.1
01.03	197	23	2011	5.6	0	0.57	4.1
11.03	197	23	2066	5.8	0	0.56	4.1
21.03	186	24	2115	5.9	0	0.55	4.1
01.04	186	24	2183	10.3	0	0.53	4.1
11.04	167	25	2143	11.5	0	0.52	4.1
21.04	148	27	2093	9.5	0	0.48	4.1
01.05	129	27	2099	10.4	0	0.48	4.1
11.05	122	29	2127	10.8	0	0.48	4.1
21.05	115	29	2172	10.6	0	0.47	4.1
01.06	0	29	2236	0	0	0	0
11.06	0	27	2454	0	0	0	0
21.06	0	18	2655	0	0	0	0

Farm size			
Herd size	90	Milk Income ($)	236615
Litres	235	Concentrates ($)	0
Fat	899282	Fodder ($)	16184
Protein	42253	Nitrogen ($)	8520
Pasture used (t DM/h	33291	Agistment ($)	6826
Concentrates fed	8.7	Crop 1 ($)	1800
Fodder 1 fed	0	Crop 2 ($)	0
Fodder 2 fed	48.4	IOFC ($)	203285
Nitrogen	69.3	Cow costs ($)	82250
Conserved	8.5	Gross Margin ($)	121035
Crop 1	28.2	Cow potential	1
Crop 2	60	Part. factor	1
	0		

Appendix 4. Advantages and disadvantages of feeding diet 2

PARTIAL BUDGET FOR SUPPLEMENTARY FEEDING

Cows	235	
Milk	3.42	$/kg MS
Feed	1	kg/cow/day
Feed util.	0.95	percent offered
Feed cost	$22.33	cost/cow
Test	0.084	% milksolids
Peak	21	li/cow/day (no suppl.)
Yield	315	kg MS/cow (no suppl.)
	322	kg MS/cow (with suppl.)
Lactation	280	days in milk
Herd ave.	1.15	MS/cow/day (mean calving effect)
Response	1.600	kg milk/cow/kg suppl.

Advantages		35	7.926005		
1. Additional income					
Milk	1.000	kg milk/kg feed/day	50	days	3376
	0.084	kg MS/kg peak	30	multiplier	2025
Reproduction					
		earlier mean calvg	0	days in milk	0
	3	less culling(%)	429	per replacmt	3024
		less matings	17.50	per mating	
	3	less inductions (%)	41	$ per induct.	289
	3	less anestrus trtmt	20	$ per cow	141
Carryover					
Cow condition					
Lifetime performance					
				TOTAL ADV.	$8,855
Disadvantages					
Feed	12368	kg ration fed	47	c/kg DM	5813
Labour	1.5	hours per day	10	$/hour	750
Machinery	1.5	hours per day	19.73	$/hour	30
Capital	3000	investment	5	% interest	150
Other		R&M extra			250
				TOTAL DISAD	$6,993
				NET CHANGE	$1,863
				/COW	$7.93

Comments

1 Risk - guaranteed feed quantity cf. nitrogen.

2 Post-peak response is a function of management (feed cow condition)