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## Increasing per cow milk solids production in a pasture-based dairy system by manipulating the diet: A review

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### ABSTRACT

Research suggests that the genetic potential for milksolids (MS) production by New Zealand dairy cows is considerably under-exploited under current grazing conditions. There is also a growing awareness that only small improvements in MS production per cow can be achieved with pasture-only systems on high producing New Zealand dairy farms (i.e. those producing 315kg MS/cow or 1,000kg MS/ha). The review identifies nutritional limitations of a pasture-based diet as one of the barriers to further increases in per cow MS production. It is argued that further increases in per cow production on New Zealand's high producing (in terms of per cow MS production) dairy farms is contingent upon the need to balance the pasture-based diet for protein, carbohydrates, fibre, minerals and vitamins through strategic use of feedstuffs. One of the keys to successfully balancing a pasture-based diet is to obtain better data on the nutritional status of pasture throughout the year so that the most economic feedstuffs which will balance the ration can be identified.

**Keywords:** dairy nutrition; milksolids production; pastoral systems; supplements.

### INTRODUCTION

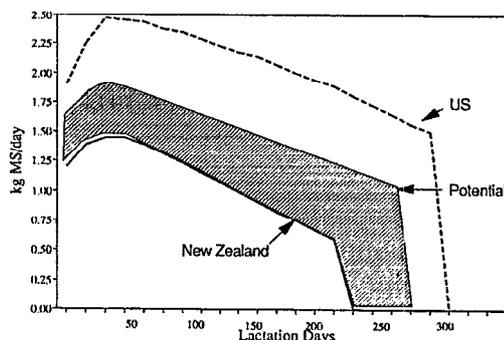
The CANZ (Canadian/New Zealand Genotype-Environmental Interaction) study of daughters from top New Zealand and Canadian bulls under the feeding and management conditions of each country showed that New Zealand and Canadian dairy cows have a similar potential for milk production (Peterson, 1988; Graham *et al.*, 1991). Similarly, a comparison study of 10 international dairy genotypes in Poland ranked New Zealand sired cows third and fifth for milk yield under "field" and "intensive" feeding conditions, respectively, and first for total solids yield per kg liveweight (Stolzman *et al.*, 1981; Jasirowski *et al.*, 1983). Significantly, the milk yield of the New Zealand daughters was equal to or above the overall averages for both sections of the study, thereby supporting the CANZ trial evidence that New Zealand cows are of comparable genetic merit to those overseas.

Thus, it is clear that cows in New Zealand have the capacity for much higher levels of production than are currently being achieved (only 1% of herds exceeded an average of 350 kg MS/cow in the 1990/91 season: LIC, 1992). As well as being a significant "waste" of the genetic potential of New Zealand cows, the low per cow production in this country is also costly. This is due to the financial advantages of higher per cow production through the dilution of herd maintenance costs, rearing costs and other per head costs (Satter *et al.*, 1992; Holmes *et al.*, 1993a), as well as benefits (discussed later) which accrue as a consequence of developing high per cow production systems (i.e. due to better nutrition).

A stylised comparison of milk production curves for cows in New Zealand and the United States (US) is presented in Figure 1. This shows that New Zealand dairy cows have a lower peak production, a more rapid decline from that peak (i.e. less persistence), and a shorter average lactation (226 days for 1991/92 season (LIC, 1993) vs 305 days in the US)

due to the seasonal pattern of calving and generally abrupt cessation of milking in the autumn and early winter in New Zealand (Parker and Muller, 1992; Parker *et al.*, 1993). In contrast, year-round production systems in the US allow longer average herd lactations to be achieved more readily, however calving intervals tend to be greater than 365 days as a consequence (Parker and Muller, 1992). Since such differences in production between New Zealand and US herds are largely independent of the genetic merit of animals from the respective countries, they must be nutritionally induced.

**FIGURE 1:** Stylised lactation curves for high producing New Zealand (—) and US (- - -) dairy cows. The production potential for pasture-based cows in New Zealand is indicated by the shaded area.



The CANZ trial highlights this point, since milksolids production by both Canadian and New Zealand bred heifers under New Zealand feeding and management conditions was only about 55% of that achieved under Canadian conditions (Peterson, 1988; Graham *et al.*, 1991). Peterson (1988), in summarising results from the trial, concluded that the apparent constraint to production was the New Zealand feeding and management system, which relies almost exclusively on grazing pasture.

The purpose of this paper is to review the limitations of, and opportunities for, high per cow milksolids (MS) production under New Zealand's pasture-based dairying systems. The discussion primarily focuses on dairy farms where production is above 315 kg MS/cow (about 7% of dairy herds in 1990/91: LIC, 1992), or where medium levels of per cow production (280–315 kg MS) are achieved under high stocking rates, resulting in at least 1,000 kg MS/ha, although it is acknowledged that milksolids output can be restricted below these levels by inadequate pasture growth in some regions (e.g. Northland). This focus is because of the growing awareness amongst farmers and researchers that only small improvements in MS production per cow can be achieved with pasture-only systems on New Zealand farms where cows are producing at high levels (Hodgson, 1989; Holmes, 1989; Bryant, 1990a, 1992). In fact, Bryant (1990b) stated that "*Perhaps the most disturbing feature [of present grazing systems] is that the best farmers have nowhere else to go. They have reached the attainable levels of production and the challenge is no longer there.*" This may be true for a pasture-only system, but it will be shown that this is not the case for a pasture-based system, given the untapped genetic potential for MS production in New Zealand herds.

#### LIMITATIONS OF THE CURRENT PASTURE-BASED SYSTEM

Milk production from pasture-based dairy systems is essentially a function of the annual yield and quality of pasture, the percentage of pasture production utilised, the efficiency of pasture conversion to dairy products (Holmes *et al.*, 1987), the genetic potential of the herd for milk production, and the management skill of the farmer in matching pasture production with the feed requirements of the herd. Some of these parameters are reviewed in detail in the following sections.

##### Dry Matter Production

Climate, soil fertility and management inputs (pasture species and composition, fertiliser, pesticides, grazing) set an upper limit to the amount of pasture which can be produced in a year (Matthew, 1992). The maximum dry matter (DM) yield that is likely to be achieved with New Zealand pastures is around 20 tonnes/ha if the sward is maintained in a condition that will allow maximum growth rates (Hodgson, 1989). Data reproduced by Hodgson (1989) describing the annual DM production of New Zealand pastures on 'top' farms and at Research Stations over a 50 year period from 1940 suggests that there has been little progress in improving pasture productivity. In addition, Thom and Prestidge (1988), Hodgson (1989) and Matthew (1992) all suggest that little further progress in increasing the potential DM yield of the main temperate pasture species can be expected, except where special purpose forage crops are introduced. Thom and Prestidge (1988) also contend that leading dairy farmers are already achieving DM production levels of this order.

In addition to the limit that maximum DM yield places on milk production, the distribution of that DM production throughout the year is of similar importance (Goold, 1985; Leaver, 1987; MacMillan and Henderson, 1987). In fact, the pattern of the milk

production curve for New Zealand herds is largely determined by the corresponding pasture growth curve. MacMillan and Henderson (1987) highlighted the effect of seasonal growth patterns of pasture in an analysis of production increases per cow in New Zealand between 1960 and 1984, and concluded that the increases were almost entirely due to increases in peak production. Furthermore, they suggested that the higher peak production was largely a consequence of the genetic gain which has been made in the herd being exploited during spring, but not at other times of the year when "seasonal factors" had greater impact. Improved utilisation of pasture is also likely to have had an effect on per cow production in early lactation (Holmes, 1989). Annual increases in production per cow would, however have been greater if the rate of decline in daily production during summer could be reduced (i.e. greater persistence), and lactation could be extended (MacMillan and Henderson, 1987). Both of these improvements could be achieved by decreasing the current pasture restrictions in summer and autumn (i.e. pasture DM production and quality).

##### Feed Quality

Few detailed assessments of the temporal changes in nutritive components of pasture have been reported in New Zealand, especially on a whole farm basis. Hutton (1962) presented a profile of pasture digestibility over a calendar year, but details of other parameters affecting pasture quality relative to the nutritive requirements of a dairy cow were presented over a shorter time frame (Hutton, 1961). Other studies of pasture quality have also been short-term, and/or describe a limited number of quality parameters (Johns, 1955; Kingsbury, 1965; Bailey and Ulyatt, 1970).

Pasture quality issues need to be considered alongside DM yield data. This is well demonstrated by modelling studies, which suggest that the introduction of new pasture species with higher annual DM yields or less seasonal DM production should result in improved milk production (Goold, 1985; Thom and Prestidge, 1988; Moloney, 1991; Brookes *et al.*, 1993), but these generally have not been achieved in practice (e.g. Thomson, 1988; Thomson and Barnes, 1990; McCallum and Thomson, 1992). This is because modelling studies are usually based on DM yield (a crude measure of the nutritive value of pasture), and a high level of utilisation of the extra pasture grown. Poor animal production responses in the field are also likely to reflect the emphasis that plant breeders have placed on characteristics such as adaptation to climate and soils, persistence and seasonal growth, annual DM production, and resistance to pests and diseases, rather than the feeding value of pasture plants under animal grazing (Laidlaw and Reed, 1993). Feed quality therefore remains a key limitation of pasture-based dairying through its impact on DM intake and the nutritive value of feed ingested (Ulyatt and Waghorn, 1993).

As well as poor feed quality *per se*, variation in feed quality during the season also impacts on production. Despite claims that there is scope for improving the feeding value of plants without jeopardising their ability to perform and persist under grazing, and that testing under commercial farming conditions at an early stage of breeding should be adopted (Clark and Wilson, 1993), achieving significant benefits for the New Zealand dairy industry through this type of plant breeding programme is likely to take at least 15 years.

## Utilisation

Even on the best managed dairy farms only 80-85% of the DM grown is likely to be utilised (Smetham, 1973). This is because pasture utilisation is a function of: grazing management; physical factors, such as soil type and stocking rate; rainfall prior to and during grazing (Smetham, 1973; Holmes and Dine, 1992); and the decision-making skills of the farmer. High levels of utilisation can be achieved by different methods of grazing management (Bryant, 1990a), but only at very high stocking rates did McMeekan (1960) show that rotational grazing would provide increases in milk production compared to set stocking management. Subsequently, Thomson (1989) attributed only 4% of the increase in milkfat production over a 30-year period at the Waimate West demonstration farm to "pasture management".

Given that the potential annual DM pasture yield has not increased much on the 'top' farms in New Zealand (see earlier), it can be inferred that utilisation of pasture (i.e. through higher stocking rates and grazing management skill; Holmes, 1989; Thomson, 1989), and perhaps pasture quality (both through more digestible pasture species and better grazing management), have been responsible for much of the increase in milksolids production per farm which has occurred since 1950 (LIC, 1992, 1993). Increases in the yield of milksolids per cow due to genetic improvement will also have had an effect (the national herd breeding index for milkfat increased by 26% for cows sired by artificial breeding bulls between 1955 and 1990: LID, 1990). There is, however, an upper limit to stocking rate (and hence herd size per farm), which is a function of the farmer's management objectives and the pasture production and soil characteristics of the farm (Wright and Pringle, 1983; Holmes and Parker, 1992).

For these reasons there are likely to be limited opportunities on many farms to improve pasture utilisation through further increases in stocking rate. Marginal improvements in the efficiency of pasture usage could be achieved by modifying paddock shape, altering the frequency of feeding, and manipulating herbage allowance (Ulyatt and Waghorn, 1993). Nevertheless, on farms where a high standard of grazing management is already practised the annual proportion of pasture consumed by dairy cows can probably only be increased by up to 5%, since, as already stated, the maximum sustainable utilisation of pasture for dairy production is probably between 80 and 85% (Smetham, 1973). If a pasture to milksolids conversion of 14:1 (kg DM eaten:kg MS<sup>1</sup>) is assumed (Holmes *et al.*, 1987), for a farm producing 20 t DM/ha and utilising 85% of the pasture grown, production from these pastures would be 1,100-1,200 kg MS/ha, which corresponds to the level of production already achieved on the best dairy farms in New Zealand.

## Herbage Intake

The physical capacity of the dairy cow to consume pasture is another limitation to milksolids production in a pasture-based system. In fact, Chase (1993) contends that Dry Matter Intake (DMI) is the most important variable influencing cow productivity. Intake capacity can be represented as a function of grazing

time (GT; minutes/day), biting rate (BR; bites/minute) and intake per bite or bite size (BS; g/bite):

$$\text{DMI (kg/day)} = \text{GT} \times \text{BR} \times \text{BS} \times 1000.$$

These three grazing behaviour variables have been quantified in grazing studies (mainly in the United Kingdom). Grazing time ranges from 420-700 minutes/day for dairy cows, with a median of around 510 minutes/day (Leaver, 1985). The relationship between GT and pasture availability is linearly inverse, but is also influenced by sward structure, daylight hours and level of production (Journet and Demarquilly, 1979). These authors reported an increase in GT of 12 minutes per kg increase in milk production for cows producing 20-35 kg milk/day under rotational grazing. The rate of biting for dairy cows is in the range 55-65/minute and is usually slightly lower with larger bite sizes (Leaver, 1985), however the maximum number of bites per day by a dairy cow is thought to be around 36,000 (Stobbs, 1973). A cow grazing at 60 bites/minute for 510 minutes/day would take 30,600 bites/day. The most critical determinant of DMI is BS (Leaver, 1985). A wide range in pasture BS's have been measured or predicted for different breeds and cow sizes (Leaver, 1985, 1986), with a typical average of around 0.35g DM/bite over a grazing season (Leaver, 1986). Table 1 demonstrates the application of grazing behaviour variables to the pasture DM intake requirements of a 450 kg cow producing at different levels in mid- to late-lactation.

According to Leaver (1985), dairy cows under pasture grazing conditions usually consume less than 3.0% of their bodyweight (BW) as DM, but in high producing cows this may be increased to the equivalent of 3.25% BW (Leaver, 1985). Intake estimates obtained by the pasture difference technique indicate that DMI of up to 4.5% of BW may be achieved on high quality pasture (Holmes, 1987; Holmes *et al.*, 1993b). Nevertheless, the data presented in Table 1 suggests that on a herd basis (averaging intake of 3.4% BW) the potential for milk production is about 27 kg of 4% fcm/day if high quality pasture is the sole source of energy, and environmental conditions and activity are such that maintenance energy requirements are minimised. In contrast, US lot-fed herds with average consumption greater than 4% of their BW as DM are not uncommon, and levels of up to 6.7% have been attained for periods within a lactation (Chase, 1993).

Grazing behaviour calculations such as these are only indicative of intake potential. The physical capacity of cows to consume feed, and their efficiency in converting feed into milk, must set a maximum level of milk production per cow. Although this limit is not yet apparent, genetically superior cows producing 25,000 kg over 365 days have been identified (Bauman *et al.*, 1985; Chase, 1993). Factors which impact upon DMI of pasture, some via influences on bite size, include the bulk density and water content (DM%) of a forage, the morphological structure of leaf and stem components (these affect the animal's ability to reduce the particle size of ingested feed by chewing), feeding frequency, nutritive value, particle size, and palatability (Ulyatt and Waghorn, 1993). Through their influence on DMI these factors ultimately limit milksolids production in pasture-based systems by restricting both the peak and persistency of dairy milk yields.

<sup>1</sup> Equivalent to 25:1 kg DM eaten:kg MF. This is an average figure – the pasture to milk conversion ratio varies substantially depending on factors such as feed quality and cow condition (Holmes *et al.*, 1987).

**TABLE 1:** Theoretical estimates of grazing parameters to achieve dry matter intakes necessary for milk production by cows at maintenance.

Milk production <sup>a</sup> (kg 4% fcm)	Intake requirement			Bite Size <sup>c</sup> (g DM)	Grazing Time <sup>f</sup> (min)
	% BW <sup>b</sup>	kg DM <sup>c</sup>	kg FW <sup>d</sup>		
14	2.5	11.3	75	0.37	373
18	2.8	12.6	84	0.41	416
23	3.1	14.0	93	0.46	462
27	3.4	15.3	102	0.50	505
32	3.6	16.2	108	0.53	535
36	4.1	18.5	123	0.60	610

<sup>a</sup> Adapted from NRC (1989).

<sup>b</sup> BW = Body weight.

<sup>c</sup> DMI may be up to 18% less in early lactation.

<sup>d</sup> Fresh weight of herbage consumed at 15% DM.

<sup>e</sup> Assuming GT = 510 minutes/day and BR = 60/min (i.e. 30,600 bites/day).

<sup>f</sup> Assuming BS = 0.3 g DM and BR = 60/min (i.e. 33 min/kg DM).

## Summary

The previously discussed limitations, plus those related to the managerial ability (and personal goals) of the farmer and the costs of feed relative to the value of milk products, are restricting the milksolids production of New Zealand's pasture-based dairy cows to levels well below their genetic potential. The preceding overview of pasture production and utilisation indicates that farmers with already high producing pastures and herds will make only slow progress in increasing per cow production from improvements in pasture yield or utilisation. Potential does exist, however to increase lactation peak by reducing limitations imposed by diet quality and intake capacity. Similarly, the US-type lactation curve (Fig. 1) shows that higher levels of mid- to late-lactation production can be achieved if cows are provided with a high quality diet. Improved late lactation milk production, however is also related to the peak and persistence of early lactation yield, since total lactation yield will be enhanced by a factor of 200-220 for each unit increase in peak yield (Holmes *et al.*, 1987; Lean, 1987). Extending lactation by improving diet quantity and quality in late summer/early autumn is a further option for increasing milk production. It is therefore apparent that a strategic approach is required to provide additional feed, or more 'nutritionally appropriate' feed, at these key points in lactation.

## STRATEGIES TO OVERCOME LIMITATIONS

The provision of extra feed, or more "nutritionally appropriate" feed, to alleviate the limitations of pasture-based dairy production can be achieved in a number of ways, including: extra fertiliser inputs (e.g. nitrogen and phosphate); irrigation or drainage to reduce soil water deficits and surpluses; use of high yielding forage species (e.g. maize, chicory), bought-in feedstuffs (concentrates, industry by-products) and off-farm grazing and/or pasture hay or silage to increase feed supply; and diet additives to improve the digestive efficiency of pasture. It should again be noted that considerable potential exists on most farms producing low levels of milksolids per hectare to improve pasture production through improved soil fertility, better grazing manage-

ment and more productive pasture species before embarking on the strategies discussed below.

## Use of Nitrogen

Nitrogen (N) is most often, and most profitably, applied to pastures as a tactical input to increase production during or following periods of slow pasture growth (O'Connor *et al.*, 1989; Roberts *et al.*, 1992). Inadequate planning of the time of N application relative to pasture deficits and weather and seasonal conditions often means that the response to N is small and unreliable (Field and Ball, 1978; Roberts *et al.*, 1992). Nevertheless, studies by Bryant *et al.* (1982), Holmes (1982) and Thomson *et al.* (1991) all showed substantial DM and milk yield responses to a variety of application approaches (regular dressings; two split applications; single heavy application).

Nitrogen response results such as these need to be considered alongside recent research evidence which suggests that adding N to spring pasture with already high levels of crude protein may have negative effects on milk production and herd fertility (Williamson and Fernandez-Baca, 1992). There is also some concern that frequent applications of N will lead to grass-dominant swards that have a lower nutritive value than mixed legume-grass swards (O'Connor, 1983; Caradus *et al.*, 1993). Furthermore, the experience of European agriculture shows that caution should be exercised before adopting high N input systems because of its possible negative impact on the sustainability of the land and water resource. Thus, while N offers a relatively low cost and simple method to increase pasture supply at strategic times for farmers already achieving high production levels, this extra feed probably offers the potential to increase per cow milksolids yield by only 5-10%. It also does little to alleviate either the problems of pasture quality or seasonality of pasture growth, and may exacerbate them.

## Alternative Species

Some forage species, particularly C4 varieties, have the capacity to grow more feed per unit area than traditional temperate grass and clover swards (C3) (Lean, 1987). The best known alternative for the top half of the North Island is maize. Dry matter yields of around 30 t/ha have been recorded in the Waikato region and this has produced silage with a protein and energy content of 6 to 9%, and 9 to 10.3 megajoules of metabolisable energy (MJ ME) in the DM, respectively (Densley, 1992, *pers. comm.*; Macky, 1992). At these yields, maize provides a method to increase forage DM production on dairy farms, especially where this is incorporated in a long-term pasture improvement programme. Other pasture and forage species may also play an increasing part in the feed supply in New Zealand, particularly as the effects of climate change continue to take effect (Baars *et al.*, 1990; Field and Forde, 1990). However, as discussed in relation to pasture quality, improving dairy cow milk yields is dependent on the quality as well as the quantity of feed grown and it will therefore be necessary to address the nutritional deficiencies for milk production of many of the high yielding forage species (a simple example is the low protein content of maize relative to the requirements of a lactating dairy cow).

## Industry By-products

By-products comprise the waste materials left after the processing of food, fibre and industrial materials. In New Zealand these include vegetable peelings, fruit pulp, low grade fruit, cooking fat, whey, brewers' grains, animal fat, sawdust and paper. While the feeding of food by-products to livestock is common in many overseas countries (Bath, 1981), limited use has been made of these materials in New Zealand. Recent analyses of the nutritive value of horticultural by-products such as apple pulp, sweet corn husks and reject kiwifruit indicate that these materials have a high feeding potential for dairy cattle (Bramwell *et al.*, 1993). Similarly, whey has been identified as a suitable feed source for animals (Morris *et al.*, 1985), and sugar-extracted crop residues and protein extracted from pasture also have potential (Donnelly, 1983; Piggot, 1983). Nonetheless, for such feeds to be utilised effectively they would need to be offered in conjunction with other feeds (e.g. pasture) to ensure that the animal received a balanced diet. Further research is required to establish the most effective method of feeding and storing by-products, but the integration of this aspect of dairy cattle feeding with the expanding horticultural industry in particular would provide some dairy farmers with a significant alternative feed source and at the same time reduce problems associated with the traditional methods of by-product disposal (e.g. landfill dumps).

## Ration Balancing

A recurring theme throughout the preceding review is that one of the major limitations to milk production in pasture-based dairy systems is the inappropriate (for maximal production) nutrient mix of a pasture ration. Although some farmers provide mineral licks and may drench with minerals during periods of the year, supplementation of the diet of New Zealand cows is usually in the form of pasture derivatives such as hay or silage. The nutritional adequacy of the diet is therefore almost totally dependent on the composition and quality of the pasture offered, and the type of grazing management imposed.

Ration balancing refers to the practice of providing animals with a diet that contains all the necessary nutrients to achieve the required level of production and to maintain the animal in a healthy state. For sustained and high levels of milk production the cow's diet should be nutritionally balanced for energy, protein, carbohydrates, fibre, minerals and vitamins (Satter *et al.*, 1992; Muller, 1993). A balanced diet is achieved by altering the proportions of the feeds which make up the diet with a wide range of feed-stuffs, providing their nutritional composition is known. This method of feeding is routinely practised in the pig and poultry industries in New Zealand, as well as the dairy industries in many other countries.

In a pasture ration two of the key imbalances are the level and types of readily fermentable carbohydrates, and the high level of rumen degradable protein (Ulyatt and Waghorn, 1993). Various physico-chemical differences between a pasture and a US "Total Mixed" ration (e.g. long, tough and very elastic fibres in pasture cf. short, brittle fibres in maize silage or lucerne) also impact on the nutritive balance of a pasture ration (Ulyatt and Waghorn, 1993). With respect to pasture,

soluble carbohydrate levels will often be higher in immature pastures and fibre levels higher in mature pastures (Bailey, 1962), but these variations are unlikely to be of sufficient magnitude, or appropriately timed, to meet the cow's needs at a particular stage of lactation. It is not surprising then that research in the US clearly shows that pasture alone is inadequate for achieving high per cow production (Muller, 1993). Feeding to meet a cow's requirements for lactation, rather than simply offering the lowest cost and most readily available feed, is the primary reason for the occurrence of the sharp divergence in milk production between US and New Zealand cows since 1950 (Ulyatt and Waghorn, 1993).

To balance a pasture diet for grazing cows, information is required on the total daily nutrients required, projected dry matter intake, quantity of pasture offered, and the nutritional parameters of the pasture to be grazed (Muller, 1993). Much is known about the first two factors, however information on the quantity and quality of pasture is generally provided on a DM basis rather than as a more detailed description of nutritive value. Detailed pasture quality information throughout the year (e.g. regional average) is therefore necessary to give initial indications of when changes in pasture quality can be expected. Such information for New Zealand pastures exists in only very crude terms at present (Johns, 1955; Hutton, 1961, 1962; Bailey, 1962, 1964; Kingsbury, 1965; Bailey and Ulyatt, 1970; Rattray and Joyce, 1974), but is the focus of a number of current research programmes (Bryant, 1993; Parker, W.J., *pers. comm.*). Detailed pasture quality information will be necessary for individual farms if ration balancing of pasture-based diets for cows is to be achieved (Kellaway and Porta, 1993). Armed with such information, nutrition consultants and farmers can begin to balance the cow's diet by providing supplements which will complement the inadequacies of the available pasture at the lowest cost. Evidence that such an approach to supplementary feeding can work is provided by the work of Dellow *et al.* (1988) and Wanjiaya *et al.* (1993), in which the efficiency of utilisation of protein in lucerne and white clover was improved by supplementing the animals with fermentable carbohydrates.

Technology to rapidly and reliably measure pasture quality will therefore need to be purchased by feed evaluation centres so that the information necessary to balance the cow's diet is available. Near infra-red reflectance spectroscopy (NIR) is widely used in the US and the United Kingdom to inexpensively and quickly measure feed quality (Baker and Barnes, 1990). NIR technology needs to become a feature of New Zealand dairy research and farm management.

With Ration Balancing as part of the "culture" of pasture-based dairy farmers effective use of supplements, including "alternative" feeds such as industry by-products, could be made. To date this has not occurred in most supplementation studies in New Zealand (for example: Bryant and Donnelly, 1974; Bryant and Cook, 1977; Morris *et al.*, 1985; Bryant, 1993), since the supplement has instead been viewed mainly as a means of supplying more DM to the cow, rather than a means of balancing the diet (Kellaway and Porta, 1993).

One example of the provision of a more balanced ration to cows is the use of maize silage plus summer-autumn pasture with a meal additive (e.g. including a by-pass protein supplement). Such a ration could provide a practical and cost-

effective means of increasing early- and late-lactation production (Dairy Exporter, October 1991, p.20; July 1992, p.9; September 1992, p.25-27). Despite the successes of such an approach (Moller, 1994, *unpublished trial results*), such ration balancing is still being done largely “in the dark” due to inadequate supporting information on pasture quality.

## CONCLUSIONS

Pasture, animal and management factors which contribute to milk production from pasture have been discussed. The “feed barrier” encountered on farms with high utilisation of pasture from well managed swards, and the prospect for only small improvements in potential DM yield from C3-based pastures, means that additional inputs of feed (particularly those containing limiting nutrients) to these farms will be required if milksolids production is to be increased. This would exploit the significant, unused genetic potential of New Zealand dairy cows for milk production. Physical limitations, such as bite size and the DM content of pasture, limit the daily energy intake and hence the milk yields of cows under pasture-only systems to less than about 27 kg milk per day - well below the levels of 35-45 kg/day being achieved by animals of similar genetic merit under confined feeding (Muller, 1993). These pasture and animal “barriers”, together with the prospect for higher milksolids prices in a world with less restricted trade, indicate that alternatives to pasture-only feeding systems for dairy cattle need to be considered to improve the diet quality and energy intake of cows on the ‘top’ producing 10-15% of New Zealand dairy farms.

The addition of feeds to balance pasture-based dairy diets has the potential to increase both per cow and per hectare milksolids production, as well as to improve fertility and reproductive performance within the herd (Williamson and Fernandez-Baca, 1992). However, historical fluctuations in prices for milksolids received by dairy farmers indicate that it will be necessary to develop farming systems which provide flexibility to quickly and inexpensively change from high to low input feeding strategies.

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