Limits to and optimising of milk production and composition from pastures

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Summary

Milk production by cows grazing improved pastures in south–eastern Australia is limited by the ability of the animal to prehend and process herbage. These constraints prevent cows from achieving their genetic potential. To remain competitive, dairy production systems in southern Australia will need to remain low cost and continue to focus on productivity gains. Recent research on understanding the key determinants of herbage and nutrient intake, and the interactions between grazed pastures, supplements and cows is reviewed. Deficiencies in knowledge in terms of optimising the conversion of pastures and supplements into milk (immediate marginal milk production responses) are highlighted. Future possibilities to manipulate milk composition to improve physical functional properties, those properties that are influenced by processing conditions and dictate the suitability of products for subsequent uses, or to enhance the concentrations of compounds with beneficial effects in human nutrition, are discussed.

Keywords: milk, composition, grazing, supplements, nutrient intake, prehension, digestion, immediate marginal milk production responses, substitution

Introduction

In southern Australia, dairy production systems are primarily pasture–based with seasonal calving. Milk production in Australia has grown by 70% over the last 25 years, with most of the increase occurring in the last 10 years. This growth in production has been accompanied by increasing diversity in dairy farming systems within and between regions, fewer but larger farms, increased herd size, increased production per hectare and per cow, and greater use of brought in supplements.

The dairy industry in south–eastern Australia is export orientated, and its dependence on exports means that production systems must remain low–cost to be internationally competitive. Following deregulation on 1 July 2000, there are two contrasting schools of thought in relation to prices farmers will receive for their product, namely:

- under deregulation, the differential in the farm gate prices for market and manufacturing milk will eventually disappear, with payment not based on end use
- there will be differentiation in prices for milk used in different products (liquid milk, milk with specific attributes for specific products or ingredients, and milk for bulk commodities) and averaging of prices across farms may disappear

Under both scenarios, farm gate prices will vary depending on quality and timing of supply. If the latter forecast prevails, there will be different systems to produce different products for different markets. However, the majority of milk will still be processed into bulk commodities and a low cost of production will be a prerequisite for a viable business.

Seasonal patterns of pasture growth and changes in nutritive characteristics of herbage are primary constraints to producing milk of specified composition, and both will affect the management and feeding systems used by farmers within and between regions. The increasing use of purchased supplements has heightened the need to understand the interactions between pastures, conserved feed inputs, concentrate supplements and grazing cows to effectively contain the cost of production, manage inputs per unit of production, and to produce milk with a specific composition.

In optimising milk production from pasture, compromises are needed to achieve the right balance for pasture growth, herbage nutritive characteristics, persistence of sown species and utilisation. The skill of varying grazing and supplement management to overcome the major problems of large seasonal and between year differences in growing conditions will become increasingly important. The principles of feed planning and understanding the supply of pasture in relation to demand at the cow and herd level are not new, but they are becoming more important in containing feed costs in order to remain competitive in world markets. Hence, balancing seasonal feed demand with expected pasture supply, and feed budgeting to estimate how available feed may best be used to ensure optimal or target levels of milk production, is essential in making profitable decisions on pasture use. These principles have underpinned the research on milk production and composition described in this paper.

Myths and misconceptions

In recent years, research funding agencies have favoured input/output experiments or systems demonstrations (often as farmlets) as a sufficient form of investigation, and have been reluctant to support work on understanding the underlying mechanisms. However, the fundamental understanding of mechanisms is a prerequisite for successfully transferring results between systems and locations.

A second matter is the misconception that information generated in controlled feeding systems practised in the northern hemisphere can be directly applied to grazing systems. This is fraught with danger. A clear example is that extra energy supplied in early lactation to stall–fed cows will give a higher immediate marginal milk production response than a similar amount of energy fed in mid or late lactation. This principal is clearly understood and applied in controlled feeding systems. At grazing, the reverse is often true (Stockdale 1999a).

A third matter, frequently used as a red herring by those who promote sales of formulated feeds, is the ongoing debate about the relative costs of growing pasture vs feeding grain/concentrates. Once the decision is reached to produce milk in a pasture–based system, then pasture growth and utilisation must be optimised from the inputs used to generate returns on costs already incurred. To change from a pasture–based to, or towards, a feedlot system is a long–term business decision where all costs involved need to be considered. Such strategic decisions should not be based on simple comparisons of costs of particular feeds at a point in time.

Nutrient intake at grazing

Intake regulation by grazing dairy cows is complex and is undoubtedly affected by characteristics of the pasture, such as pasture mass, sward composition, digestibility, nutrient concentrations, and management of grazing. Relationships between pasture allowance, pregrazing pasture mass and herbage intake by dairy cows are now well understood (Wales *et al.* 1998, 1999a). We have found strong positive relationships between intake and allowance that are often curvilinear. The point at which these relationships plateau varies with pasture mass and pasture type, and level of milk production. Increasing the pre–grazing pasture mass results in an increase in pasture intake at common allowances. The relationships are also influenced by species composition, with cows grazing clover dominant pastures consuming more than those grazing grass dominant swards at equivalent pasture allowances and masses (Stockdale 2000).

In establishing these relationships, we have found it is important to understand the grazing behaviour of cows. The times spent grazing and ruminating, the patterns of these events throughout the day, and the rates of intake of herbage have important implications in optimising responses to supplementary feeds. For example, rumen fluid pH is often less than 6.0 for considerable periods of the day in cows grazing high digestibility pastures (Williams *et al.* 1999; Wales *et al.* 2001) and this is clearly related to the pattern of intake (Figure 1). In cows grazing pasture and supplemented with cereal grain, declines in rumen pH follow ingestion of grain and grazing periods immediately after milking. Recovery in rumen fluid pH occurs when rumination time exceeds eating time. The time for which pH remains below 6.0 is affected by the amount of pasture consumed and the species composition, with pH being lower on clover than on grass (Williams *et al.* 1999). Rumen pH will also be affected by the amount and type of supplements that are given.

As well as pasture conditions and management practices, we recognize that animal and environmental factors such as cow size, milk yield, stage of lactation, disease and climatic stresses affect intake of grazing dairy cows, but these will not be considered here.

Nutrient intake at grazing, specifically the nutrient concentrations in consumed as opposed to pre–grazed herbage harvested to ground level, and the degradation characteristics of energy yielding substrates and protein,

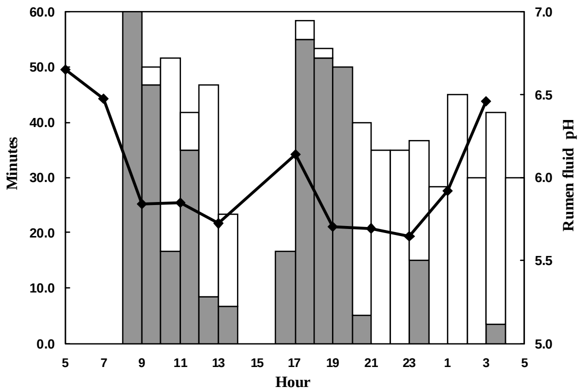

Figure 1 Associations between eating (the shaded bars) and ruminating (the open bars) and rumen fluid pH (the curve) in cows grazing subterranean clover (*Trifolium subterraneum*)–based pastures supplemented with 5 kg cereal grain pellets fed in two equal amounts immediately after milking at 0530 and 1430 h. [Source: W.J. Wales, unpublished data].

has assumed more importance as dairy farmers have aspired to ‘balancing nutrients’ in relation to cow requirements. While this is readily achieved in controlled feeding systems, at grazing ‘nutrient balancing’ is a forlorn dream unless nutrient intake from grazed herbage can be predicted. Decision support tools (Cohen and Doyle 2000) have been developed in Victoria that enable the prediction of digestibility (or estimated metabolizable energy; ME), crude protein (CP) and neural detergent fibre (NDF) concentrations in strip grazed pastures and in the herbage consumed by specifying the time of year, dominant species and pre–grazing pasture mass. Recommendations on the use of formulated concentrates in isolation from such knowledge must be questioned.

Most dairy farmers employ strip grazing or small paddock rotational grazing systems through lactation. Under these conditions, the differentials in digestibility between the leaves and stems of pasture plants are small (Stockdale 1999b), with the result that differentials between the upper and lower proportions of the grazing horizon are not large. The consequence is that cows grazing white clover (*Trifolium repens*)/perennial ryegrass (*Lolium perenne*) pastures in spring or autumn consume material that is 5 to 15% more digestible than pre–grazed herbage harvested to ground level across a wide range of pasture allowances (Wales *et al.* 1998, 1999a; Doyle *et al.* 2000). For lower quality pastures, containing significant proportions of paspalum (*Paspalum dilatatum*) and summer growing weeds, this differential is between 0 and 5%. The predictions in the decision support tools referred to above allow for these differences between seasons.

In contrast, the concentrations of CP differ markedly between leaf and stem in white clover, perennial ryegrass and paspalum (Stockdale 1999b), and leaves are predominant in the upper levels of the grazing horizon. The result is that the concentrations of CP in consumed herbage are between 25 and 40% higher than in the pasture on offer in both irrigated and rain–fed pastures. For irrigated pastures, CP concentrations in consumed herbage are seldom below 17%, and can approach 30%, thereby generally exceeding requirements for cows in early, mid or late lactation. This has clear implications for the choice of supplement in different seasons in northern Victoria, with potential losses in milk production likely to occur because of the energy cost associated with excreting excess nitrogen. This is particularly the case in spring when pasture is plentiful and when clover dominant pastures are grazed (Cohen 2001).

In the irrigated regions of northern Victoria and southern New South Wales, it might be expected that CP could limit milk production responses where cows graze paspalum–dominant pastures and are supplemented with significant amounts of cereal grain to overcome energy deficiencies. However, Wales *et al.* (2000) found that substituting either canola or cottonseed meals for some of a cereal grain supplement, fed at 8.0 kg DM/cow per day, did not affect milk production or concentrations of fat and protein in milk. This indicates that either CP concentrations in pasture would need to be extremely low or high amounts of low CP cereal grain would need to be fed to warrant the costs of providing supplementary rumen degradable or undegraded dietary protein in these environments. It was estimated that the substitution of either type of protein supplement for part of the cereal grain would reduce gross returns from the supplement under a range of feed price scenarios, unless there were significant carry–over benefits in terms of body condition or subsequent milk production. Extrapolation of recommendations for the irrigated pasture–based systems of this region to the rain–fed and, particularly, dry summer regions would be unwise, hence the need to understand nutrient intakes from pastures under different circumstances.

Herbage CP is rapidly degraded in the rumen (Beever and Siddons 1986; SCA 1990; Beever 1993), leading to absorption of ammonia and net losses in amino acids potentially available to the cow (Ulyatt *et al.* 1988; Beever 1993). It is also often suggested that high digestibility herbages supply insufficient undegraded dietary protein to meet the requirements of high producing dairy cows. In recent studies, Wales *et al.* (1999b) and Cohen (2001) estimated that spring and irrigated summer pastures supply excess metabolizable protein (digestible microbial true protein plus digestible undegraded dietary protein) in relation to requirements for spring calving cows with peak milk production of over 30 L/day. With high ruminal outflow rates prevailing in these cows, undegraded dietary protein contents of spring pastures have been estimated to be between 0.38–0.42 of the CP (Wales *et al.* 1999b). Similar values for fresh grass have been published by MAFF (1990).

Research has also improved our ability to predict intake of NDF from grazed pastures. Its concentrations in pastures are inversely related to digestibility and are lowest during winter and spring and highest in summer (Doyle *et al.* 2000). The concentrations of NDF in pasture on offer usually exceed those recommended for lactating cows, namely 30–40% (SCA 1990). However, selection may create a problem in this regard, particularly when cows graze pasture with a high clover content, since the NDF in the pasture consumed is lower (0.75 to 0.95) than in the pasture on offer (Wales *et al.* 1998, 1999a; Doyle *et al.* 2000). This occurs principally because leaves have less NDF than stems (Stockdale 1999b).

Potential milk production from grazed herbage

Seasonal variations in pasture growth rates, its availability and its nutritive characteristics limit milk production. To estimate the potential of a high producing cow (mature liveweight 550 kg) to produce milk from pasture, we have made the following assumptions:

1 sufficient pasture of high digestibility (10.5 MJ ME/kg DM) is available throughout the year to enable a pasture allowance that does not limit intake. Pasture consumed has an estimated ME of 11.6 MJ/kg DM

2 peak achievable milk yield at grazing is 32 L/day of 4% fat corrected milk (Wales *et al.* 1999a)

3 peak achievable daily intake at pasture is 4% of liveweight i.e. about 22 kg DM/cow (Holmes and Wilson 1987; Cohen *et al.* 2000)

4 the decline in milk production from the peak is linear at 5% per month

5 cows become pregnant at day 84 of lactation, they walk 2 km/day and have an energy cost for grazing of 10 MJ ME/day

6 lactation continues for 315 days and each cow starts and finishes lactation in condition score 4.5, having lost weight at 0.5 kg/day in the first third of lactation, maintained weight through mid lactation, and gained weight at 0.5 kg/day during late lactation

7 ME requirements for maintenance, milk production and liveweight change are according to SCA (1990).

Under these conditions, annual milk production is 6,700 L/cow, and pasture and ME intakes are 5,400 kg DM and 63,000 MJ, respectively. This level of production is substantially less than could be achieved by the same cow fed indoors, where most of the constraints imposed on feed intake by grazing, such as the need and effort to harvest and process about 200 kg of fresh herbage each day at peak intake, have been removed.

In practice, grazing cows are unable to achieve this level of milk production without supplements. Production of the quantities of pasture needed to achieve the desired level of intake is not sustainable; its energy content is not constant throughout a year and rate of pasture growth varies widely. To illustrate this, the ME provided by irrigated perennial pastures at different levels of pasture production can be compared with the requirements of cows under different stocking rates and peak milk yields (Figure 2). The assumptions made for these scenarios have been listed by Stockdale *et al.* (1997). Wherever the lines depicting ME required for milk production are uppermost, the areas between these and the lines depicting the ME provided by pasture indicate the magnitude of the energy deficit. Conversely, wherever the line depicting ME provided from pasture is uppermost, pasture provides energy in excess of the cows' requirements.

In these examples, ME from pasture is always insufficient to meet cow requirements in autumn and winter. At the low stocking rate, pasture production in spring provides sufficient ME to achieve both levels of milk production, provided grazing management is of a high standard. At the high stocking rate, maximum levels of pasture production are needed in spring to meet the cows' requirements from pasture. At this stocking rate and the lower level of pasture production, there is always a deficit between requirements of cows at both levels of production and the ME available from pasture.

While this approach to estimating deficits in ME supply provides a reasonable framework for estimating carrying capacity or setting stocking rates in pasture–based dairy systems, it oversimplifies important aspects of the interactions between cows, pastures and supplements.

Pasture—supplement interactions

When supplements are fed to grazing dairy cows, two types of interaction need to be considered, namely substitution and associative effects of the feeds during digestion. Studies examining these effects under pen feeding conditions are abundant, whereas those that examine them at grazing are scant. Our purpose in this section is to highlight the variability in immediate milk production responses to supplementation of grazing cows and to summarise recent data examining the mechanisms that might underpin whether supplements are effective or not. We recognize that immediate marginal milk production responses under–estimate the full benefits of supplements in terms of improved condition score, subsequent milk production or reproductive performance (Broster 1972; Holmes and Wilson 1987).

Immediate marginal milk production responses

Accepted theory from controlled feeding experiments is that additional ME in early lactation will result in greater immediate marginal milk production responses than an equivalent amount of ME fed in mid or late lactation (e.g. Stockdale *et al.* 1987). However, this may not always be the case in grazing systems (Table 1). It is apparent from Table 1 that at similar pasture allowances, immediate marginal milk production responses to supplements are higher in mid and late lactation than in early lactation. In addition, Walker *et al.* (2001) have reported diminishing milk production responses as the amount of supplement fed is increased. A key reason for this is an increasing level of substitution as the feeding of supplements increases (Stockdale 2000). Therefore, while a number of factors affect the immediate marginal milk production response to supplements, namely pasture allowance, stage of lactation, and the amount and type of supplement fed, the nutritive characteristics of the herbage consumed also play an important role.

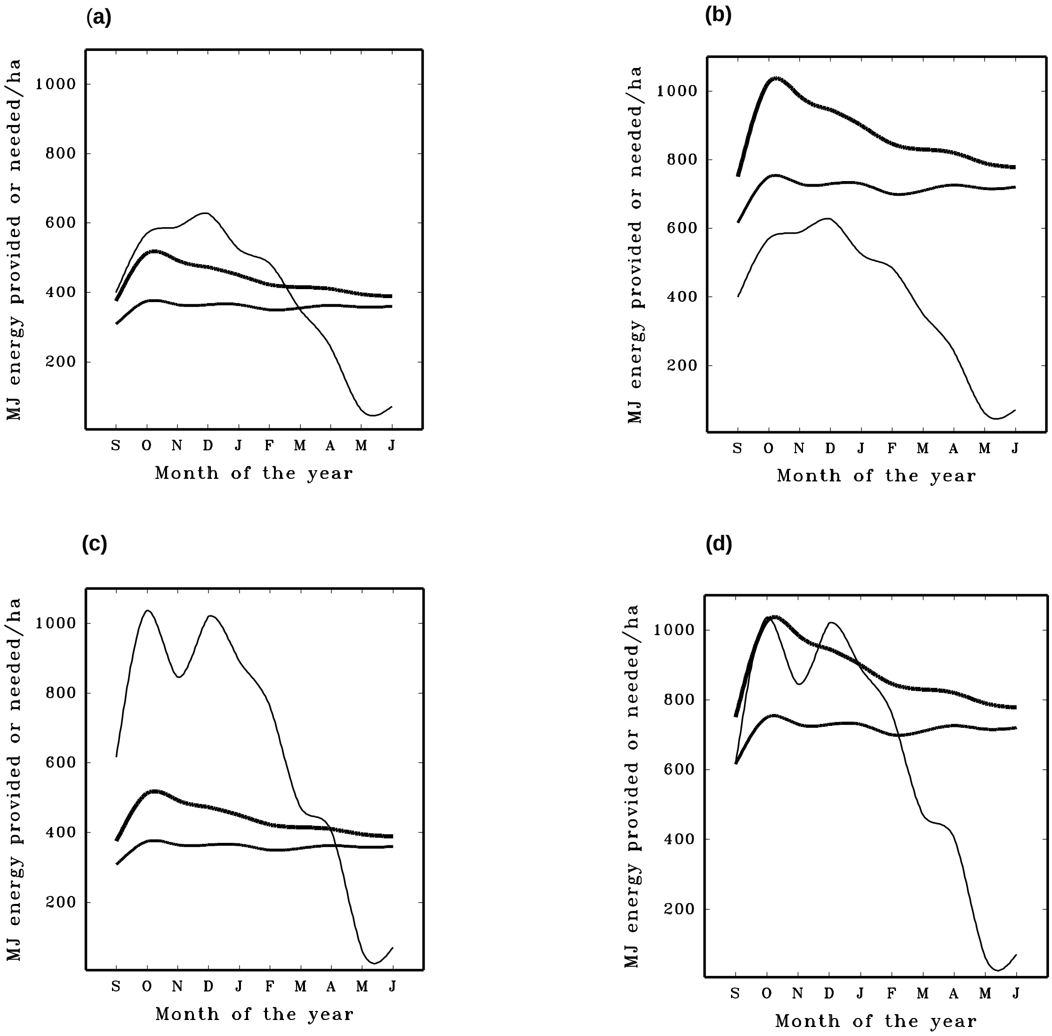

Figure 2 Metabolizable energy available from herbage (thin lines) where annual pasture production is 12 (a and b) or 18 t DM/ha (c and d) and ME requirements of cows with peak milk yields of 20 (medium lines) and 30 litres/day (thick lines) at stocking rates of 2.5 (a and c) and 5.0 (b and d) cows/ha. [Source: Stockdale *et al.* 1997].

Poor responses in early lactation

Herbage allowance is the key driver of dry matter and ME intakes from unsupplemented pasture (Wales *et al.* 1998, 1999a). One consequence of increasing herbage allowance is an increase in the substitution rate when grazing cows are given concentrate supplements (Stockdale 2000). Furthermore, a large proportion of the variation in the immediate marginal milk production responses observed when cows are grazing highly digestible pastures is due to substitution. The ME intake of unsupplemented cows at grazing has been found to be negatively correlated with the immediate marginal milk production response to moderate amounts of grain supplementation (Figure 3). While levels of substitution increase as the amount of supplement fed increases (Stockdale 2000), substitution only goes some of the way towards explaining the low immediate milk production responses to supplements in spring when most cows in south–eastern Australia are in early lactation.

Stockdale (1999a) postulated that immediate marginal milk production responses were inversely related to the ME concentration in the pasture being consumed. He suggested that the amount of NDF in the diet may be low enough in spring to impair rumen fermentation and, if this deficiency could be alleviated, improved responses would follow.

There is a need to question some indices of rumen and ruminant efficiency. For example, with conserved forages supplemented with concentrates, it is generally accepted that NDF digestion is impaired when rumen pH falls below 6.0. De Veth and Kolver (1999) have demonstrated *in vitro* with basal high digestibility herbage diets, that NDF digestion is not depressed significantly until rumen pH falls below 5.8. As indicated earlier, cows grazing high digestibility pastures without supplements have a rumen fluid pH below 6.0 for considerable periods of the day, but it is uncertain whether the digestion rates of NDF in high digestibility pasture under these circumstances are suppressed compared with the digestion rate of the same substrate

Table 1 Immediate marginal milk production responses (FCM, fat–corrected–milk; F, milk fat yield; P, milk protein yield) to concentrate supplements (Suppl., kg DM/cow per day unless specified otherwise) fed to grazing dairy cows.

Reference	Suppl.	Lactation	Pasture allowance (kg DM/day)	Unsupplemented pasture intake (kg DM/day)	Substitution (kg DM/kg DM)	Marginal milk responses (kg FCM/ kg DM suppl.)	(kg F+P/ kg DM suppl.)
Whole lactation							
Fulkerson *et al.* (2000)	0.84 t/year	Whole				1.6	0.093
	1.71 t/year	Whole				1.0	0.072
Immediate responses							
Stockdale (1999a)	5.0	Early	31	16.4	0.43	0.4	0.044
Wales *et al.* (2001)	4.5	Early	19	11.2	0.18	1.0	0.081
Stockdale (1999a)	5.0	Mid	30	15.0	0.29	1.2	0.087
Wales *et al.* (1999a)	5.0	Mid	27	10.2	0.21	1.3	0.091
	5.0	Mid	48	13.7	0.43	0.8	0.063
	5.0	Mid	27	13.1	0.34	1.0	0.075
	5.0	Mid	48	15.2	0.43	0.8	0.055
Walker *et al.* (2001)	3.0	Late	25	12.1	0.02	1.1	0.076
	5.0	Late	25	12.1	0.18	1.2	0.082
	7.0	Late	25	12.1	0.21	1.1	0.074
	9.0	Late	25	12.1	0.19	0.9	0.068
	10.4	Late	25	12.1	0.28	0.9	0.049
	3.0	Late	31	15.0	0.23	1.0	0.085
	4.9	Late	31	15.0	0.39	0.6	0.042
	5.9	Late	31	15.0	0.47	0.5	0.038

in a rumen where pH remains above 6.0. It would also be valuable to know the composition of the microbial population in the rumen in these cows, its stability and how it compares to populations in cows grazing less digestible herbage. In all of our studies on the effects of unsupplemented pasture intake on rumen fermentation patterns, the ratio of lipogenic to glucogenic volatile fatty acids (VFA) in rumen fluid has always been above 4:1, indicating that there should be sufficient precursors for milk fat synthesis.

Recent research has examined the effects of moderate amounts of grain (5 to 6 kg DM/day) with and without additional NDF (as hay) on rumen fermentation patterns, digestion rates of the basal pasture and immediate marginal milk production responses. When pelleted grain supplements were fed, milk fat depression occurred sometimes when the VFA ratio was below 4:1 and sometimes when it was above. Y. Williams and W.J. Wales (unpublished data) have found that grain supplementation of cows grazing high digestibility pastures differentially depresses *in situ* digestion of NDF from the basal herbage and hay. For example, disappearance rates of NDF from the highly digestible pasture in nylon bags incubated in the rumen were reduced from 6.2%/h to 4.3%/hr. In contrast, disappearance rates of NDF from the hay were reduced from 4.2%/hr to 1.9%/h. Addition of hay to the grain supplement did not significantly improve disappearance rates of NDF from either substrate relative to that in the grain supplemented cows.

The use of NDF to indicate sufficiency of fibre needs to be questioned given the variations in what comprises the NDF extract between plant parts and pasture species. Mertens (1997) has proposed a method of estimating the physically effective NDF for housed dairy cows fed formulated diets. The extrapolation of this system to grazing dairy cows, where the spatial distribution of components within a sward and the management of grazing affect bite size, bite frequency, rate of ingestion and rumination characteristics, may not be appropriate. A new technique or approach to estimating the physical effectiveness of the cell wall components of pastures is probably needed.

Genetic merit of cows

Fulkerson *et al.* (2000) have recently reported on a 5 year experiment that examined milk production responses of high (representing the industry norm in 25–30 years time) and low (representing the industry

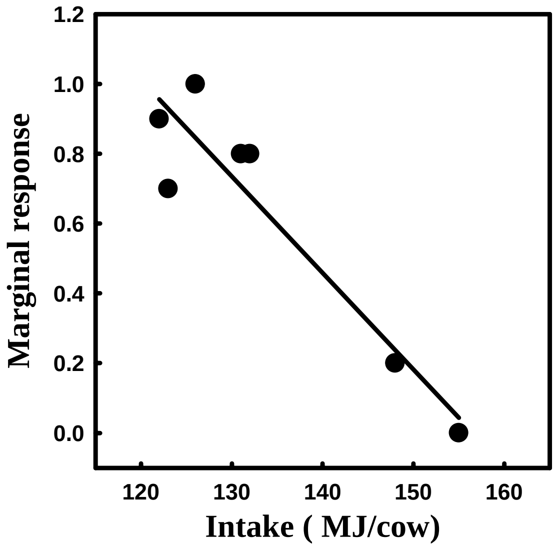

Figure 3 The relationship between immediate marginal response (kg 4% fat corrected milk/kg concentrate DM) to about 5 kg of pelleted cereal grain supplement by cows in early lactation grazing high digestibility pasture, and the intake of metabolizable energy from the pasture by cows given no supplement. [Source: W.J. Wales, unpublished data].

norm in the 1990s) genetic merit cows under different production systems. The basal system was predominantly pasture–based with about 0.34 t of concentrates fed to cows in summer. This was compared with two more intensive systems where pastures were supplemented with either 0.84 or 1.71 t of concentrates per cow. There was a significant interaction between genetic merit and level of concentrate feeding when comparing milk production from the different herds. The high genetic merit herds produced 8.4% more milk and 8.0% more fat plus protein than the low merit herds at the lowest level of concentrates, but 12.7% more milk and 12.9% more fat plus protein at the highest level.

This interaction was also evident when examining production per cow, the differences in milk fat plus protein per lactation between high and low merit cows being 27 kg at the lowest amount of concentrates and 49 kg at the highest amount (Fulkerson *et al.* 2000). Whole of lactation milk production responses to concentrate feeding for the medium amount of concentrates (calculated by reference to the low supplement group) were 1.6 and 1.9 L milk/kg DM for the low and high genetic merit cows, respectively. At the highest amount of concentrates, responses were 1.0 and 1.2 L milk/kg DM. That is, responses to supplement feeding diminished as the amount of supplement fed was increased, but the responses were greater for high genetic merit cows. This information can be compared with the short term responses recorded in Table 1 to gain some insight into the different responses obtained in long– and short–term research.

To optimise responses in milk production to each additional increment of supplement fed, a sound understanding of the interactions between pastures and supplements is required. For example, the responses reported by Fulkerson *et al.* (2000) were for high stocking rates (equivalent to low pasture allowances and, hence, herbage intakes) with concentrates fed tactically (for example, in autumn when responses would be expected to be higher due to a greater energy deficit, than in spring). Knowledge of the nutrient content of all feeds in the diet is also essential in getting the balance right.

Potential to influence milk composition

Considerable emphasis has been placed on genetic improvement of dairy cows to improve milk solids production and, more recently, novel techniques are increasingly being used to alter the composition of the protein and other fractions. While it is possible to increase milk protein concentration in grazing cows through appropriate supplementation, it is difficult to manipulate the composition of the protein. However, it is possible to manipulate the physical functional properties of milk through nutrition and management and to manipulate the concentrations of compounds of importance in human nutrition (Walker *et al.* 2000a). Physical functional properties are those that are influenced by processing conditions and dictate the suitability of products for subsequent uses. They include solubility, heat stability, reheat viscosity, gelation, emulsification and foaming.

As an example, we have examined the effects of nutrition on conjugated linoleic acid (CLA) concentration in milk fat. The average concentration of CLA in Australian milk is about 1.20% of milk fat. This concentration is considerably higher than for cows fed conventional total mixed rations (0.12 to 0.60%; Ma *et al.* 1999). The higher the level of pasture in the diet, in general the higher the level of CLA (Kelly and Bauman 1996; unpublished results from Kyabram and Ellinbank, Victoria). However, this relationship is complex and a quadratic response in milk CLA to cereal grain supplementation has been shown in dairy cows grazing predominantly paspalum pastures in northern Victoria (Walker *et al.* 2000b).

This work indicates that there is potential to develop systems to produce milk with specific attributes, whether these are related to the nutritional profile of the milk or dairy products or to improved processing performance.

Conclusions

The pasture–based segments of the Australian dairy industry are in a good position to use relatively cheap pasture together with a diverse array of energy and protein yielding supplements to produce milk competitively. Optimum combinations of pasture and supplements for milk production at an individual farm level depend on resource issues (land and labour) and on fluctuations in prices received for milk and costs of inputs. This means both strategic (long term) and tactical (within a short period, e.g. season) feeding strategies and decisions are important to the farm manager. Optimum decisions will only be made with a sound understanding of the underlying nutritional principles and interactions that occur between pastures, supplements and grazing cows. In the longer term, generalised advice will become a thing of the past.

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