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Response of lactating cows to grain-based concentrates in northern Australia

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Abstract

This article discusses key issues for future research into concentrate feeding in dairy pasture systems in northern Australia. It is suggested that emphasis should be on whole-farm, input-output studies and the factors determining the levels of response obtained. Responses on-farm are higher than those in research station experiments where a reduced number of factors are investigated, and short-term experiments generally provide a misleading picture of milk responses to concentrate.

Whole-farm models to predict cow and farm milk output under a wide variety of situations are necessary for optimising forage-concentrate inputs and to assist long-term property planning. A better understanding of substitution of concentrates for pasture is necessary in order to understand the equilibrium between cow live weight and condition, pasture availability and level of supplementation.

Seasonal supplementation techniques need to be investigated to counteract lowered pasture quality and quantity and the effects of heat stress in summer and autumn. Protein sources need to be compared with different pasture types and at high levels of milk yield per cow.

Introduction

It is interesting to reflect on the first major review on "Limitations to Dairy Production in the Tropics" conducted at Wollongbar in 1971. At that time the level of grain feeding was around 1–2 kg/d (Salkeld 1971). Few published experiments on concentrate feeding in northern Australia were cited, and feeding recommendations were based predominantly on research from the United States and the United Kingdom (Jeffrey 1971).

Grain-based concentrates are now an integral part of dairy feeding systems in northern Australia. A survey of Queensland dairy herds in 1986–87 showed that 0.86 t/cow of grain-equivalent concentrate was fed per year. By 1990–91, this figure had increased to 1.49 t/cow (Kerr and Chaseling 1992). Calculations suggested a 40% increase in milk production per hectare over the 4 years between the surveys, half of which came from supplemental energy sources such as grain, molasses and protein meals.

This paper reviews the literature on concentrate feeding and discusses why farming systems in northern Australia have evolved to use increasing levels of grain-based concentrates. Issues considered are the physical environment, the low quality of tropical grasses upon which the industry has historically depended and the financial returns from feeding concentrates. Future areas of research are suggested in the light of changes in farm practice over the last 20 years.

Time effects

Whole-farm input-output studies (Table 1) generally reveal responses of 1.0–1.4 l milk/kg grain, which are higher than those recorded in controlled experiments. In short-term experiments of less than 2 months duration, responses of 0.3–0.6 l/kg are normally recorded (Table 2) and give a misleading picture of the economics of grain feeding (Cowan 1985; Kellaway and Porta 1992). Full-lactation experiments have generally recorded higher responses to concentrate feeding than short-term experiments and closer to the responses recorded in whole-farm studies (Table 2).

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From the recent state-wide survey of Queensland dairy farms, Kerr and Chaseling (1992) developed equations to predict farm milk output for irrigated and dryland farms. These response coefficients to supplementation support the conclusions from Tables 1 and 2, but the equations also show the importance of other major input factors on whole-farm production. It is these other factors and their interrelationship that are often ignored in experiments.

Table 1. Response to concentrates in whole-farm input-output studies in northern Australia.

Study	Response	Level of concentrate
	(kg milk/kg grain)	(t/cow/lactation)
Rayner and Young (1962)	1.1	<0.5
Jeffrey *et al.* (1970)[1]	1.28	<1
Rees *et al.* (1972)	1.1	<1
Kerr *et al.* (1993)	1.2–1.6	0–2
Kerr *et al.* (1993)	0.89 (dryland) 1.4 (irrigated)	0–2.5

[1] Assumed 4.5% butterfat.

Irrigated farms:

Mi = 35598 (±25101) + 1169 (±465) C + 1.4 (±0.2) G + 9.1 (±1.6) N. (R^2 = 0.92; $P<0.0001$)

Dryland farms:

Md = 41295 (±32019) + 2384 (±372) C + 0.89 (±0.17) G − 1170 (±206) A + 0.226 (±0.05) H + 58 (±13.5) R + 7.8 (±2.8) K. (R^2 = 0.92; $P<0.0001$)

where Mi = milk output from irrigated farms (l)
Md = milk output from dryland farms (l)
C = cow numbers
G = grain-equivalent fed (kg)
N = nitrogen fertiliser applied to the farm (kg)
A = farm area (ha)
H = hay and silage fed (kg)
R = rainfall (mm)
K = potassium fertiliser applied to the farm (kg).

We conclude that the duration of the experiment needs to be considered in determining the economics of concentrate feeding and all experiments, even those over a full lactation, underestimate the responses achieved in whole-farm input-output studies. The reasons for these differences are not fully understood, yet are important in assessing the economics of concentrate feeding strategies.

Table 2. A comparison of milk responses to concentrates in short and longer-term experiments.

Study	Duration of feeding	Amount fed	Milk response	Comment
		(kg/d)	(kg/kg)	
SHORT-TERM				
Stobbs (1971)	10 d	4.0	0.5	mid-lactation
Royal and Jeffrey (1972)	14 d	2.7	0.5	mid-lactation
Cowan and Davison (1978)	4 wk	3.0	0.8 FCM[1]	restricted pasture
		3.0	0.3 FCM	*ad lib.* pasture
McLachlan *et al.* (1991)	8 wk	2.7	0.3	molasses
		5.1	0.4	molasses + grain
LONGER-TERM				
Colman and Kaiser (1974)	5-6 mth/yr	390 kg/yr	0.9	oats
Chopping *et al.* (1976)	lactation	3.6	0.7	molasses
Cowan *et al.* (1977)	36 wk	0.6	1.03FCM	maize
Chopping *et al.* (1980)	36 wk	1.2	0.8	molasses
		2.4	0.6	
		3.6	0.6	
Davison (1991)	lactation	3.0	0.9	molasses

[1]Corrected to 4% fat.

Early lactation

Carryover effects

Cowan *et al.* (1975) demonstrated the importance of carryover effects of early lactation and the interaction with stocking rate, in cows fed for 50 days post-calving at 0 or 3.6 kg grain/d. More pasture on offer at the lower stocking rates allowed a better carryover response for the whole lactation. While high stocking rates will generally give a better response to concentrates in the short term (Figures 1 and 2) they will lead to a reduced response in the longer term (Cowan *et al.* 1975) (Table 3).

Table 3. Immediate and full-lactation milk responses to feeding in the first 50 days of lactation (Cowan *et al.* 1975).

Stocking rate (cows/ha)	Response (kg/kg) Immediate	Full lactation
1.3	0.6	3.1
1.6	0.6	2.9
1.9	0.9	2.7
2.5	0.5	0.4

Level of grain and distribution

The response in early lactation is also influenced by the level of grain fed. In a study by Davison *et al.* (1985), cows were fed at 4 different levels for the first 100 days of lactation. There was a curvilinear response to level of concentrate defined by the equation:

$$M = 13.9 + 1.77(\pm 0.48)\,G - 0.18\,(\pm 0.06)\,G^2.\ (P<0.01)$$

where M = milk yield (kg/d)

G = grain intake (kg/d).

The responses derived from this equation are shown in Table 4. The response rate is only part of the story as the economics of production are dependent on the total milk yield obtained less the cost of concentrate. However this study suggested that too high a level of feeding in early lactation would reduce the initial response.

There is still considerable debate amongst farmers, farm consultants and research workers about the optimum means of distributing concentrate over a lactation. This is despite work in Queensland and elsewhere (Rakes and Davenport 1971; Davison *et al.* 1985; Leaver 1988) which suggests no benefit to complicated systems

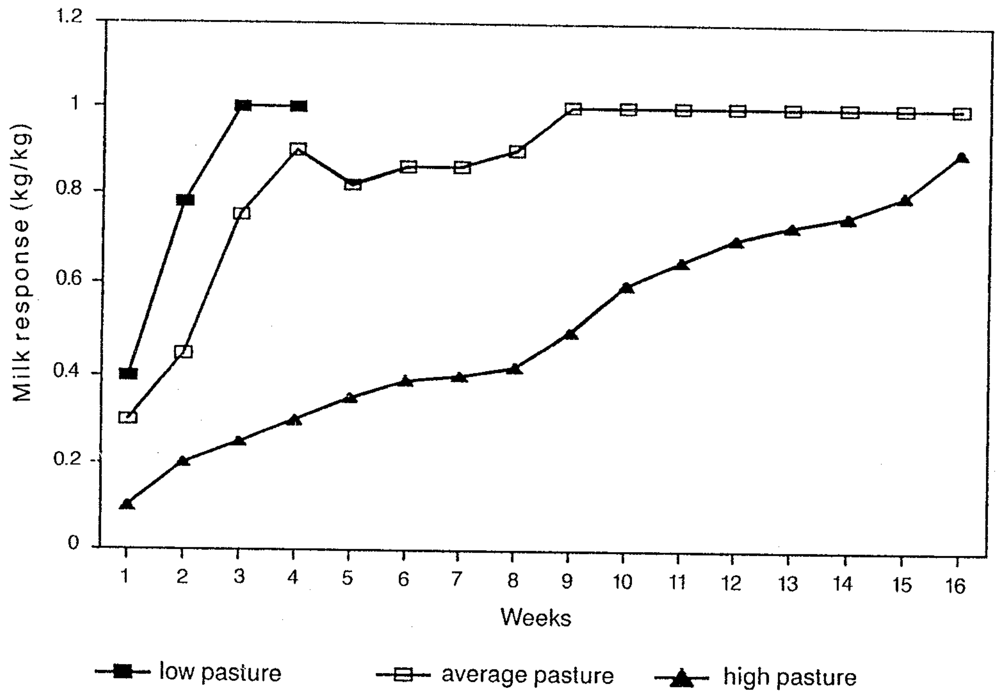

Figure 1. Changes in milk yield responses with time to molasses or grain fed at different levels of pasture on offer (Davison *et al.* 1982).

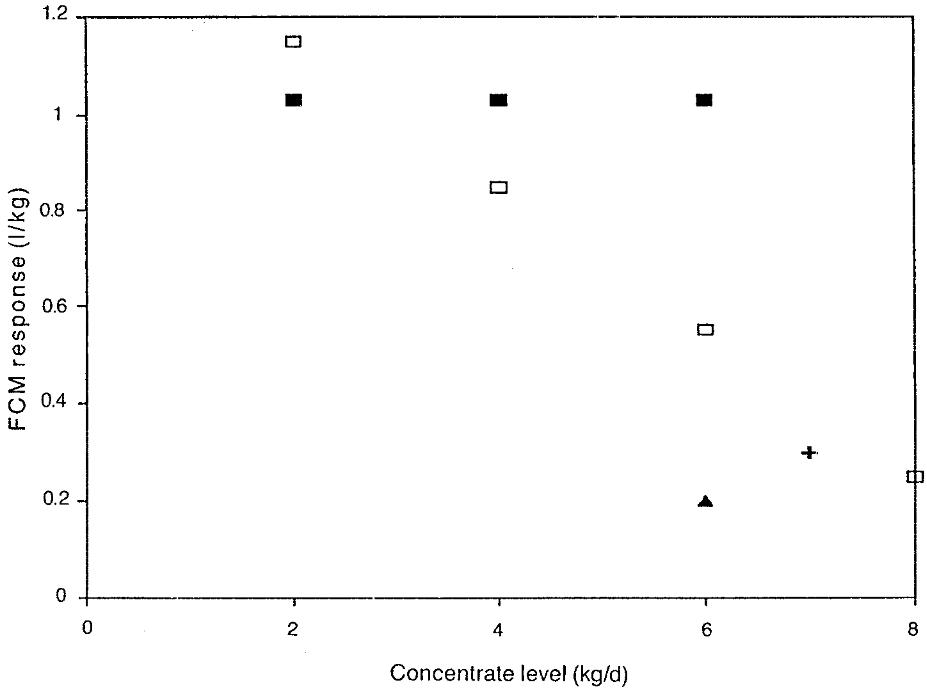

Figure 2. Variation in fat-corrected milk (FCM) yield responses with level of concentrate fed in four different experiments at Kairi Research Station (■ Cowan *et al.* 1977; ▲ Davison *et al.* 1991; □ McLachlan *et al.* 1993; + Walker *et al.* 1992).

of feeding compared with flat-rate feeding for herds producing up to 7000 l/lactation. However no work exists beyond this level of milk yield. As top herds in northern Australia are now producing well in excess of 8000 l/lactation, this research needs to be extended. In light of the large influx of north American genetic material into the Australian dairy herd over the last 10 years, the theories of supplement distribution also need to be tested for cattle of different genetic milk production potential.

Table 4. The response to increasing levels of grain fed to cows in the first 100 days of lactation (Davison *et al.* 1982).

Level of grain	Incremental response	Day 11–100 milk yield
(kg/d)	(kg/kg)	(kg/cow)
1.0	1.37	1414
2.2	0.98	1493
3.5	0.51	1621
6.7	−0.64	1579

Pasture on offer and substitution

The level of pasture on offer determines not only the response to concentrate but also the time frame over which it occurs. Data collated by Davison *et al.* (1982) showed that, as pasture on offer increased, the time to reach a stable response also increased (Figure 1). At very low pasture availability, a 1 kg/kg response could be reached in 4 weeks while at high availability the same response was reached after 16 weeks.

Recent experiments by Davison *et al.* (1991), Walker *et al.* (1992) and McLachlan *et al.* (1993) have demonstrated the critical effect of pasture on offer, and the cows' ability to adapt to a level of pasture on offer, on the milk response to concentrate feeding. The low response to concentrate in the work of both Davison *et al.* (1991) and Walker *et al.* (1992) occurred with *ad libitum* levels of pasture on offer, while the higher responses of McLachlan *et al.* (1993) occurred with less pasture on offer and where milk production from pasture was well below potential (Figure 2).

In the study of Cowan *et al.* (1977), where a high stocking rate (4 cows/ha) was employed on tropical pastures, a consistently high response (1.03 kg/kg) was achieved from feeding 0–6 kg grain/d. In the study of McLachlan *et al.* (1993), on similar pastures but at a lower stocking rate (1.5 cows/ha), the response varied with level of concentrate (Table 5). Substitution is a major factor influencing the responses obtained in all these experiments. The very low response recorded by Davison *et al.* (1991) was attributed to a high substitution rate (Sr), whereas the high response by Cowan *et al.* (1977) was attributed to a very low Sr (Figure 2).

A comprehensive study from France (Faverdin *et al.* 1991) on Sr has shown that Sr increases with level of supplementation. Average Sr values were 0.7 for maize silage, 0.53 for grass silage and 0.44 for hay. Substitution was related to the energy balance of the diet.

The full effects of substitution on reproduction, cow live weight, pasture effects and dry cow feeding, heifer rearing and cull cow prices have not been studied. The research challenge for the future will be to develop models to predict responses to concentrate feeding for different levels of pasture on offer, pasture quality, cow live weight and condition and level of supplement. These models can then be used in both farm development planning and ration formulation.

Table 5. Responses to varying levels of concentrate given at a flat rate over 250 days of lactation (McLachlan *et al.* 1993).

Level of concentrate	FCM response
(kg/d)	(kg/kg)
2	1.16
4	0.85
6	0.55
8	0.24

Seasonal supplementation

Data collated from 1987–1992 from the Queensland Department of Primary Industries Herd Recording Scheme indicate that summer-calving cows produce less than winter-calving cows (Figure 3). The reproductive data from the Queensland Herd Management Scheme over the same period show highest first service failure

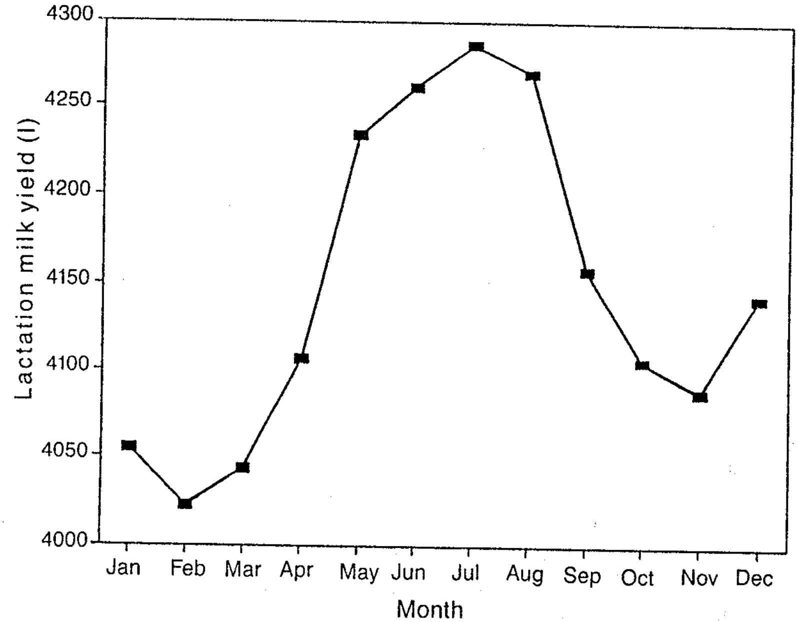

Figure 3. Lactation (300 d) milk yield by month of calving for Queensland herd-recorded cows calving from 1987–1992.

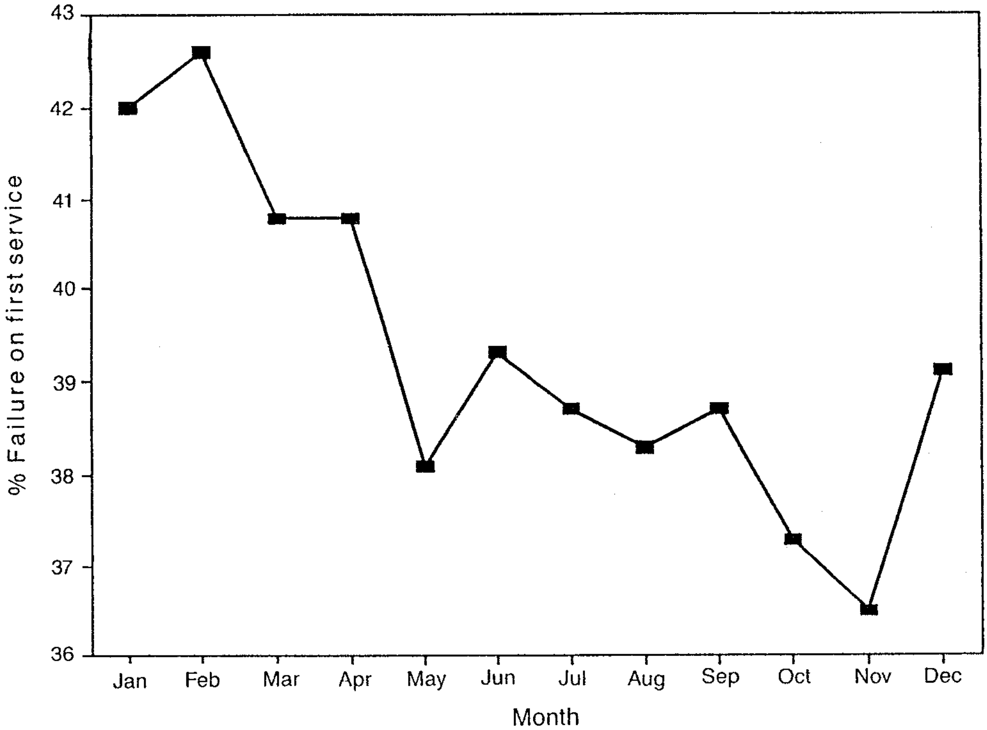

Figure 4. First service failure % in each month for cows in the Queensland Herd Management Scheme calving from 1987–1992.

rates during the summer months (Figure 4). These graphs clearly show where our future feeding and environmental research should be directed in Queensland. Work needs to be done to show whether increased supplementation or various combinations of energy, protein and fat supplements can alleviate the dual effects of low pasture quality in late summer-autumn, and thermal stress in summer (Davison *et al.* 1988).

Multiple-lactation responses

Short-term responses are clearly inadequate for an economic assessment of concentrate feeding. The long-term effects across lactations also need to be considered. Little work has been done in this area to determine the multiple-lactation effects of different levels of concentrate or pasture availability on milk yield, milk composition, partitioning of nutrients and reproduction.

After reviewing responses to concentrate feeding over multiple lactations, Broster *et al.* (1984) concluded that there were important residual effects from one lactation to the next, largely mediated through body reserves. Other experiments (Broster *et al.* 1984) reported increased outputs per input of feed in the second lactation after generous, compared with restricted, feeding in the first lactation. Again this was attributed to the mobilisation of body reserves accumulated during the earlier generous feeding period.

A 3-year experiment by Walker *et al.* (1992) investigated 4 pasture-concentrate systems, using tropical grass-nitrogen or grass-legume pastures and irrigated ryegrass in winter. Cows were fed either 1t or 2t concentrates per lactation. There was a large increase in milk yield per cow from lactation 1 to 2, but no further increase from lactation 2 to 3 (Figure 5). This suggests that intake of pasture had stabilised by the second lactation and further increases in productivity per cow would require the introduction of a higher quality forage. It is also possible that better forage utilisation could occur through an increase in stocking rate. This may also have raised milk production per hectare in year 3 of the experiment.

It is suggested that whole-farm models need to include a prediction of when long-term equilibrium in cow intake will be reached in pasture-concentrate systems so that further gains in productivity or intake can be advanced.

Economics of feeding concentrates

The state-wide input-output study of 114 dairy farms in 1990–91 (Kerr and Chaseling 1992) demonstrated that the marginal return from feeding concentrate supplements had a bigger effect on farm profitability than milk from forage. The best-fit equation to predict gross margin per farm was:

$$GM = 117421 + 0.113\ (\pm 0.012)\ F + 0.185\ (\pm 0.021)\ G - 1940\ (\pm 164)\ V.\ (P<0.01)$$

where GM = gross margin per farm ($)
F = total litres of milk from forage (l)
G = total milk from concentrates (l)
V = total variable costs as a % of milk income.

Total variable costs averaged 61% of milk income during 1991–92 for south-east Queensland farmers in the Queensland Dairy Accounting Scheme (QDAS). Data from QDAS farms over the previous 5 years show feed costs and total variable costs rising at 1–2 c/l/yr. The farms that have been able to reduce that trend are the ones that have achieved production in excess of 5000 l/cow. The above equation suggests the use of concentrates has been more profitable in achieving this goal than the use of forages.

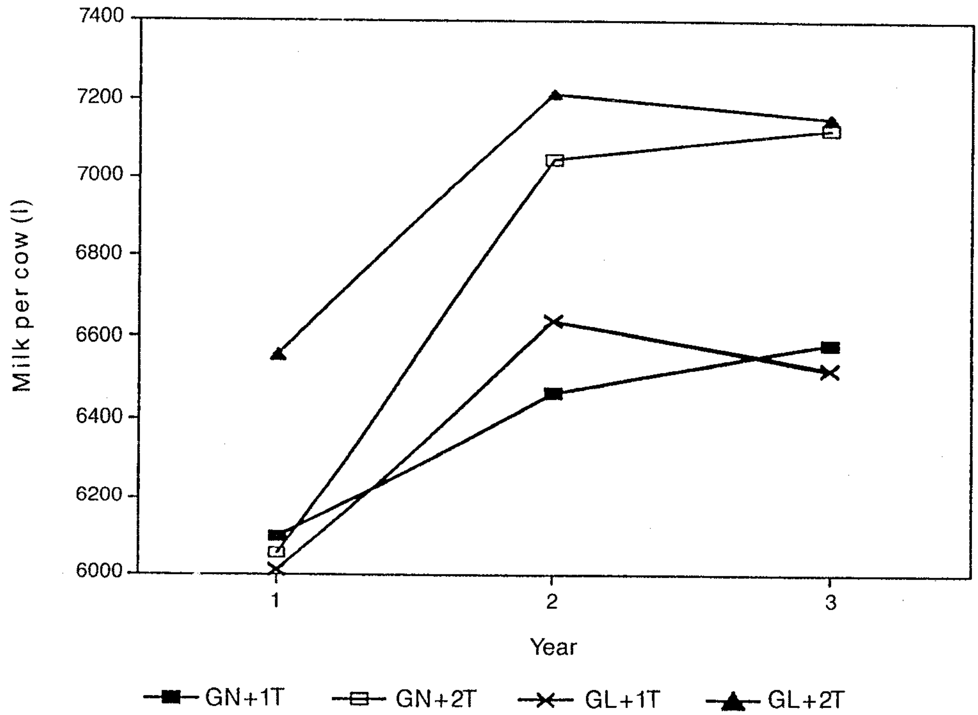

Figure 5. Changes in milk yield per cow over 3 lactations for cows grazing grass with nitrogen fertiliser (GN) or grass-legume (GL) pastures and fed 1 t or 2 t concentrate per lactation (Walker *et al.* 1992).

This farm study also demonstrated a higher milk response to concentrates on irrigated farms, where more milk was produced from forage than on dryland farms. This is in apparent conflict with research results that show a higher response to concentrates with reduced pasture availability. It may also suggest the potential for irrigated farms to increase their stocking rates to make better use of home-grown pastures. Developing models to allow this decision to be made at a farm-advisory level is an important area for future research.

Response to protein supplements

Kellaway and Porta (1992) recently reviewed the Australian literature on protein supplementation. The key issues for northern Australia were the response to protein supplements of varying degradability on different pasture types. For example, Davison *et al.* (1990) found a significant milk response to feeding meat and bone meal on tropical grass-nitrogen pastures but not on grass-legume pastures. Moss *et al.* (1992) found no response to cottonseed meal fed to cows grazing nitrogen-fertilised and irrigated ryegrass pastures, but recorded a response when cows grazed tropical grass pastures in autumn.

On-farm observations indicate milk responses to proteins with low rumen degradability at high levels of energy intake and production per cow even when cows graze high quality pastures such as ryegrass and clover. These observations need to be evaluated and responses determined for winter ryegrass and clover-dominant pastures at high levels of milk production (>7000 l/cow). Results recorded in recent experiments (Davison *et al.* 1991; Moss *et al.* 1992) at 5000-6000 l/cow may not be relevant at higher levels of milk production per cow. A comparison of protein sources of different rumen degradability on different pastures would allow incorporation of these results into computer-based, ration-formulation packages.

Future research

We suggest that more research needs to be conducted into the carryover effects of concentrate feeding over a number of lactations and how this relates to substitution effects and farm stocking rate. This work would be best conducted on farms. The results would be used to develop models to predict responses to concentrate for different levels of pasture on offer, pasture quality, cow live weight and level of supplement. These responses could then be incorporated into a range of milk price structures.

The use of supplementation to alleviate environmental effects, for example heat stress and lower pasture quality during summer and autumn, also needs to be investigated. A range of protein supplements of different rumen degradability should be evaluated at high levels of production per cow and with pastures of high nitrogen solubility.

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