SUPPLEMENTARY FEEDING OF DAIRY COWS TO INCREASE MILK PRODUCTION

T.J. KEMPTON*

Milk production systems in Eastern Australia vary from grazing improved pastures and fodder crops with strategic use of high energy supplements, to feeding complete diets under feedlot conditions. The nature of the production system within any area is dictated by climatic and economic factors. Economic return from milk production within a given area is a function of the genetic capacity of the herd, reproductive performance, genetic selection, nutrition, management, stocking rate and pricing policy of the milk produced.

Milk yields from pasture vary with pasture quality and stocking rate (King and Stockdale 1973), however, the level of production achieved by Australian dairy herds is very low compared with other countries (Nix, 1980). In 1977, Australian herds yielded 2547 l/lactation in comparison with 2870 l/cow for New Zealand, 4488 l/cow for the U.K. and greater than 5000 l/cow/lactation for Israel and U.S.A. The high levels of production achieved by other countries has been attributed to an increased level of concentrate in dairy cow rations, and to providing completely balanced diets under feedlot conditions (Bath & Bennett 1980). The relationship between concentrate usage and milk production per cow (Table 1) in the U.K. has prompted formulation of policy in Australia to explore the economics and biology of increasing the level of feeding of high energy concentrates to grazing dairy cows.

TABLE 1: Relationships between concentrate usage, milk production, and gross margins per cow and per hectare for Friesian herds in the U.K. (from Nix 1980).

Milk yield (l/cow)	Under 4,000	4,001- 4,500	4,501- 5,000	5,001- 5,500	5,501- 6,000	6,001- 6,500	Above 6,500
Average yield (l/cow)	3,742	4,316	4,787	5,245	5,722	6,185	6,742
Concentrate/cow (tonne)	1.11	1.23	1.40	1.59	1.78	1.98	2.16
Concentrate/litre (kg)	0.29	0.28	0.29	0.30	0.31	0.31	0.31
Stocking rate (cows/ha)	1.85	2.0	2.0	2.0	2.1	2.2	2.2
Gross margin/cow	217	248	279	302	331	353	380
Gross margin/ha	411	504	450	616	694	766	838

The past four years of drought in Eastern Australia have forced many producers to adopt concentrate feeding strategies which often resulted in increased milk production and so demonstrated the extent of underfeeding in Australian dairy herds. For example, in the Hunter Valley of New South Wales, in which dairying is traditionally from grazing irrigated lucerne and forage crops such as oats and ryegrass, the drought forced producers to feed grain and hay in order to maintain quota. Production figures and the marginal income above feed costs are given in Table 2.

*Department of Biochemistry and Nutrition, University of New England, Armidale, N.S.W. 2351. Australia
**Present Address - Ecosearch, P.O. Box 540, Armidale. N.S.W. 2350

TABLE 2: Marginal income above feed costs for dairy cows in the Hunter Valley supplemented with grain, or grain plus hay (Thompson, unpublished).

	Milk yield (l/d)	Marginal income above feed costs (c/day) Milk price Quota 30c/l	Surplus 13c/l	70% Quota 30% Surplus 25c/l
Pasture	14			
Pasture + 4kg grain	16.5	11	-31	-2
Pasture + 5kg grain + 7kg hay	21.0	32	-87	-3

Calculations based on grain cost at $160/t and hay at $140/t.

These figures demonstrate the potential for increased milk production through improved nutrition and feeding management, however the cost-benefit of supplementary feeding must be -assessed in relation to

1. price of the supplementary feeds
2. milk response to supplementation
3. price of milk produced, and level of production in relation to quota requirements
4. reproductive performance of the herd.

The biology and economics of supplementary feeding should be assessed in terms of the beneficial and detrimental effects of supplements on those factors that contribute to efficient milk production.

OBJECTIVES FOR EFFICIENT AND PROFITABLE MILK PRODUCTION

The following are generalised criteria on which the efficiency of dairy herds can be assessed.

* maximise dry matter (DM) and metabolisable energy (ME) production/ha with use of correct plant species, fertilizer and irrigation if necessary.
* maximise harvesting of ME by manipulating stocking rate and fodder conservation
* cows calve in good condition (i.e. body condition score 5-6)
* cows reach peak lactation and the decline in milk production per cow is not greater than 10% per month
* cows are joined by 60-70 days to achieve a year round calving pattern
* less than 18% of the cows in the dry herd
* cows reach 300 d lactation
* cows finish lactation in condition score 5
* somatic cell counts less than 200,000 counts/ml
* feed and fertilizer costs are less than 30% of gross milk income
* income is maximised above the major variable cost, feed cost

EFFICIENCY OF MILK PRODUCTION

The efficiency of milk production can be calculated in *terms* of biological, ecological and economic efficiency (McClintock 1982). For practical purposes economic efficiency is calculated in terms of gross margin per cow and gross margin per ha. The pricing structure of the market being supplied however, is of fundamental importance when calculating economic efficiency. For instance, where milk is sold on the basis of weight of butterfat, gross return/ha would favour Jersey herds. By comparison, if milk is sold on the basis of volume, gross return/ha would favour Friesian herds (see Table 3).

TABLE 3: Effect of genotype on efficiency of milk production (from McClintock 1982).

	Jersey	Friesian
Cows/ha	1.36	1.11
kg fat/ha	187	152
kg milk/ha	3596	4119
milk return/ha @ 30¢/kg	$1079	$1235
Butterfat return/ha @ $4/kg	$ 748	$ 608

The validity of this argument will change however, if the N.S.W. government adopts a pricing policy based on yield of butterfat, protein and total milk. Irrespective of the marketing structure, the aim should be to maximise the efficiency of utilisation of homegrown feed, irrespective of the level of concentrate fed. For instance, U.K. studies show that those producers with the highest returns/ha utilise a greater percentage of ME/ha, than the lower producers (Table 4).

TABLE 4: Utilisation of pasture in relation to gross margin per ha. (from Leaver 1981)

	Gross margin / ha.		
	Top 25%	Average	Bottom 25%
Utilised ME/ha ('000MJ)	77	61	46

This concept should constitute the basis for milk production systems based on grazing, provided the pastures or fodder crops can be produced at a price competitive with bought in feeds. Pastures and fodder crops should be costed on the basis of ME and protein yields/ha, and all feeds either home grown or purchased should be costed on the basis of nutritive value/$. For comparative purposes estimates of the cost of production of various pastures and bought in feedstuffs are given in Table 5.

TABLE 5: Comparative estimates of the energy value of pastures and purchased feeds (MJ/$).

Pastures and Fodder Crops		$/t DM	MJ/$
Paspalum + N		34	260
Irrigated pasture		50	220
Irrigated lucerne		55	200
Maize silage	(Camden)	93	86
	(Hunter Valley)	46	220
	(Taree)	36	270
	(Silo press)	50	200
Purchased feeds			
Lucerne hay		150	60
Dairy meal		210	48
Sorghum grain		150	80
Maize grain		160	75
Molasses		80	150

These figures. form the basis of least cost ration formulation with the objective of maximising income from milk above feed costs. Recent evaluation of many dairy enterprises indicate feed costs represent the largest variable cost (5-18¢/litre) and often exceed 30% of the total income from. milk.

MILK PRODUCTION FROM PASTURES

The levels of milk production achieved from pasture is restricted by the yield of pasture DM/ha, the nutrient density of the pasture, and the amount of fodder harvested by-the cows, as influenced by stocking rate and fodder conservation strategies. Although irrigated legume based pasture systems such as irrigated lucerne can produce considerable 'amounts of DM and ME, (12t DM and 12,000 MJ MR/ha), levels of milk production are restricted because;

1. grazing times are reduced to aid fodder budgeting, or to prevent bloat (i.e. the pastures are not continuously grazed). Strip-grazing systems effectively result in cows being underfed.

2 The nutritive value of pastures declines quickly as the plant matures'such that pastures do not remain at peak nutrient yield. The protein and energy content of pastures can vary considerably over relatively short periods of time resulting in considerable variation in the nutrient intake by grazing cows. Fluctuation in the quantity and balance of nutrients is not conducive to high levels of milk production (Bath & Bennett 1980). Consequently, cows grazing pastures and forage crops are often in negative energy balance. In an attempt to increase milk yields, and increase the utilisation of home-grown feeds, many producers green-chop the pastures/legume crops and feed to cows under semi-feedlot conditions.

Water shortages, particularly in the Hunter Valley have prompted consideration of alternate fodder production systems to maximise the yield of highly digestible forages/ha and per ML water. For instance, the water requirements of irrigated lucerne, and maize cropped for silage are 7ML/ha, and yet the potential DM yields are 12t and 24tDM/ha for the two cropping systems respectively. Although the machinery and labour costs are greater for a maize silage system, the cost/kgDM for maize silage and lucerne are similar (4-5¢/kg DM). Details of maize silage based feeding systems are discussed in more detail by Trigg (1983).

CONCENTRATE FEEDING

In an effort to increase milk yields from grazing cows, the most convenient method to meet shortfalls between energy requirements for high levels of milk production, and energy supplied from pastures is to supplement the diet with high energy concentrates. Levels of concentrate feeding vary from 0-10kg/d and are fed in the bails, or in open troughs after milking.

The severity of the recent drought in Eastern Australia has forced many producers to adopt concentrate feeding strategies and consequently realised the milk output/cow be considerably increased above the normally accepted levels. The forced high levels of concentrate feeding however, has identified major problems which require research attention.

PROBLEMS ASSOCIATED WITH CONCENTRATE FEEDING AS IDENTIFIED BY INDUSTRY:

1. Substitution effects
2. Asynchronous nutrient release with pulse feeding of grain
3. Impaired starch digestion in the intestines
4. Partitioning of nutrients into bodyweight
5. Protein to energy ratio of absorbed nutrients.

1. SUBSTITUTION EFFECTS

In cows grazing high quality pastures and forages, supplementation with concentrates can reduce the intake of pasture at a rate of 1:1 (Bines 1979), although intake of low quality forages may be increased by feeding small amounts of concentrates (Blaxter and Wilson 1963). U.K. studies show an average milk response to supplementation of 0.78kg milk/kg concentrate (range 0.30-1.6kg/kg) and that the relationship between concentrate supplementation and milk yield is quadratic (Gordon 1981). (Figure 1.)

Figure 1.

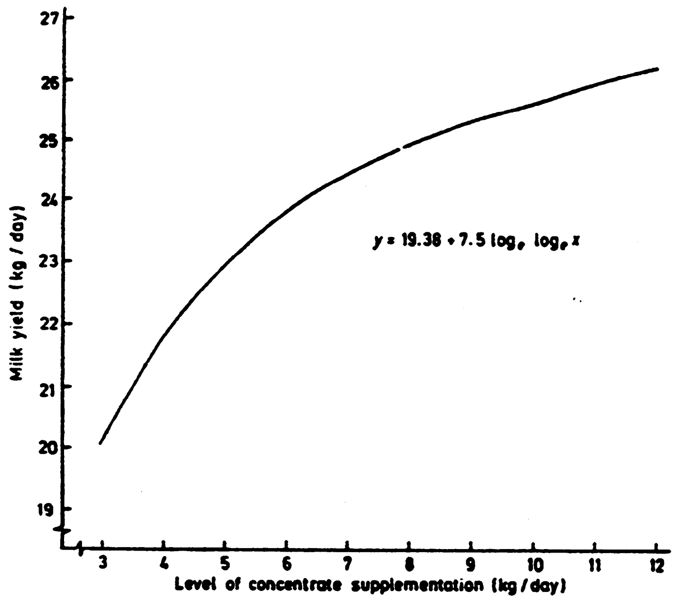


Figure 1: **The relationship between level of concentrate supplementation (kg/d) and milk yield (kg/d) during the period of feeding for spring calving cows.**

Although the level of supplementation in Australian dairy herds can be as high as 10kg grain/d, the average milk yield is seldom greater than 18-24 l/d. This suggests that even though the supplemented cows are in the most responsive phase to energy supplements, the extent of substitution is considerable. In Australian studies, milk production responses to energy supplements are given in Table 6.

The short term responses to supplementation fall in the range 0.4-0.7kg milk/kg supplement, however, long term responses of between 2.3 to 2.5 kg milk/kg supplement have been recorded. Generalised interpretation of grazing experiments is confounded however, by differences in the basal diet being supplemented, the stocking rate, the current level of milk output and the physiological state and genetic quality of the cow.

From these studies it has been estimated that forage (pasture) intake is decreased by 0.9 kg for each kilogram of concentrate fed. Under

TABLE 6: Milk production responses to energy supplements during lactation.

Supplementary period	Supplement	Response kg milk/kg supplement		Reference
1. Days 1-50 lactation	crushed maize	during feeding	0.62	Cowan et al. (1975)
		whole lactation	2.28	
2. Days 1-35 lactation	whole oats	during feeding	0.68	Thomas et al. (1980)
		whole lactation	2.46	
3. Throughout lactation	molasses	week 1-12	0.76	Chopping et al. (1976)
		week 25-36	0.44	
4. Fed at 5 months of lactation	rolled barley	during feeding	0.38	Sriskandarajah et al. (1980)
	alkali treated barley	during feeding	0.54	
5. Throughout lactation	maize soyabean	during lactation	1.01	Cowan et al. (1976)

some conditions,. this substitution effect is considered beneficial through increasing the availability of forage when the supplementary feeding stops, and increasing the overall reproductive performance of the herd (Ducker 1980). This argument however, does not take into account the decline in pasture quality and quantity over time, nor the opportunity. cost of pasture production. Estimates of pasture production for dairy cows vary from 3-5 ¢/kg DM.

Consideration should be given to providing high energy supplements to dairy cows which do not reduce the intake of pasture. For instance, alkali treatment of whole grains reduced the substitution effect of cracked grain by 50% (Ørskov et al. 1978; Sriskandarajah et al. 1980). In cows given 4 kg barley at pasture, pasture intake was reduced by 60%, whereas 4kg cottonseed meal reduced pasture intake by 30% (Rogers, unpublished). Cereal grains differ in the extent to which they are degraded in the rumen (Waldo 1973), and some grains such as cracked maize and sorghum are not extensively degraded in the rumen. Whenthese grains are crushed and fed to cattle, a greater proportion of the maize and sorghum starch granules pass directly to the abomasum in comparison to wheat and barley granules. The extent to which starch granules pass undegraded to the abomasum is related to the size and structural arrangement of the granules in the endosperm and to the content of amylose and amylopectin (French 1973). The susceptibility of starch granules in cereal grains to ruminal degradation can be altered by 'physical processing (Kempton 1982).

Fats and oils are also high energy feeds and their constituent fatty acids are attractive dietary ingredient&for increasing ME intake. The upper limit for inclusion of fat in dairy cow diets is 5-6%, because higher fat intakes inhibit cellulolytic activity of ruminal bacteria (Storry and Brumby 1979). With the advent of the technology for encapsulation of dietary ‘lipids (Scott et al. 1972) large quantities of'tmsaturated fats and oils can be included in ruminant diets with a view to increasing energy density of the diet, unsaturated fatty 'acid content of the milk, and total output of milk fat. The emulsification techniques prevent microbial hydrogen&ion of dietary unsaturated fatty acids in the rumen, by coating the lipid with a protective coat of formaldehyde treated protein which remains undegraded in the rumen and yet is hydrolysed in the acidic conditions of the abomasum (Ferguson et al. 1967). Based on this principle full fat soyabeans have been used successfully to increase butterfat yields in grazing dairy cows. (Kempton 1983).

Research priority should be directed toward development of cost effective processing techniques which will alter the site of digestion of feed supplements, and create a favourable balance of absorbed nutrients which do not inhibit intake of the basal material.

2. ASYNCHRONOUS NUTRIENT RELEASE AND AMMONIA TOXICITY

In dairy cows grazing high quality, lush green pastures, the rate of protein solubilisation in saliva and in ruminal fluid is very rapid and rumen ammonia concentrations may exceed 500 mg NH_3-N/l within 2-3 hours post ingestion of these feeds. Ammonia concentrations can decline quickly however. such that ammonia levels may be at critical levels (50-100 mg NH_3-N/l) at the time when the cow consumes large quantities of highly digestible carbohydrate. Pulse feeding of dairy cows with large quantities of concentrates may therefore create an imbalance in the rate of ammonia and carbohydrate release and carbohydrate digestion may be impaired by a deficiency of NH_3-N. It is desirable therefore, with pulse feeding systems to formulate supplements in which the rate of ammonia and carbohydrate release are synchronised with the rate of energy release in fermentation. Details of alternate non-protein nitrogen sources to reduce the rate of ammonia release in the rumen are given by Bartey and Deyoe (1981).

Subclinical Ammonia Toxicity

The high levels of rumen ammonia (>500 mg N/l) in cows grazing lush pasture may produce subclinical disorders in the metabolism and homeostasis of the cow. High levels of rumen NH_3 have been shown to decrease salivary flow rate and reduce buffering capacity of the rumen. High rumen NH_3-N also reduced fluid outflow rate from the rumen and it has been postulated that high NH_3-N concentrations may reduce the efficiency of microbial protein synthesis.

Influence of high levels of protein feeding on fertility

Reduced fertility in cows receiving diets with a high protein content has been attributed to high rumen ammonia and plasma urea concentrations, apparently through preventing implantation of the embryo in the uterus. It has often been concluded that the protein metabolism of dairy cows is not well adapted to high levels of production, since studies indicate neither an increase in the efficiency of microbial protein synthesis (Fig. 2) , nor a significant decrease in the extent of ruminal degradation

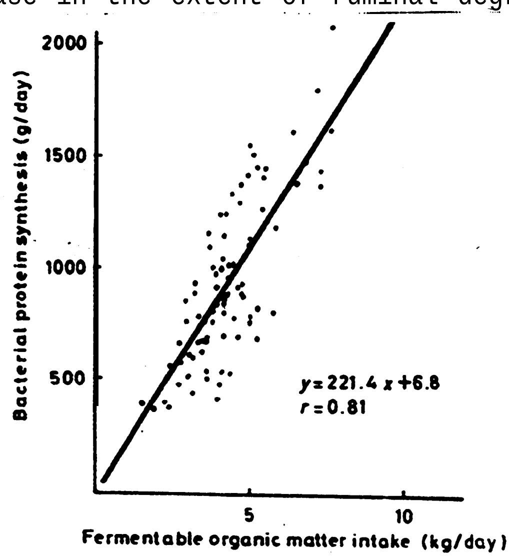


Figure 2.

The relationship between fermentable organic matter intake and bacterial protein synthesis in dairy cows.

of food protein associated with increased food intake and higher yields. Further, there is no evidence to suggest an improved utilisation of absorbed amino acids at higher levels of milk production. Therefore, in order to increase the supply of dietary amino acids to the tissues in the high yielding dairy cow to meet requirements, the concept of feeding bypass proteins has emerged.

Bypass proteins have been produced by formaldehyde treatment (Ferguson *et al.* 1967) or by heat treatment (Goering and Waldo 1974). Feeding bypass proteins to high producing dairy cows has resulted in improvements in fertility, in spite of higher levels of milk production (Table 7).

TABLE 7: Influence of protein content of the ration and protected protein on the fertility of dairy cows (from Hagemeister, Lupping and Kaufman 1981).

	Crude protein in the ration		
	16%	19%	16% (HCHO treated)
Conception rate (%)	56	44	69
Services per conception	1.79	2.25	1.45
Days empty	97.5	102.1	83.7
	Crude protein in the ration		
	12.7%	16.3%	19.3%
Days to first heat	36	45	27
Services/conception	1.5	1.9	2.5
Days open	69	96	106

In cows grazing lush pastures, first service conception rates can be as low as 30-50%, which has been attributed to specific mineral deficiencies, energy deficiency and to ammonia toxicity. A large scale feeding trial using sodium bentonite to reduce the fluctuations in rumen ammonia is currently being conducted in the Hunter Valley to evaluate the effects on reproductive performance.

Detailed research is necessary to quantitate the range of fluctuations in rumen NH3 concentration in pasture fed cows, and to ascertain if toxicities may occur from high concentrations of rumen NH_3.

3. STARCH DIGESTION IN THE INTESTINES

Efficient digestion of nutrients reaching the intestines will depend on the activity of the various digestive enzymes. In particular the activity of the starch digesting enzymes alpha amylase and maltase is pH dependent and is substantially reduced under acid conditions. Under these conditions starch is not digested in the intestines and passes from the animal in the faeces. It has been postulated (Wheeler *et al.* 1981) that inclusion of a finely ground reactive source of limestone in the diet of steers given high starch diets will adjust intestinal pH, increase starch digestion and increase production. Although considerable controversy arose over the magnitude of Wheeler's results, the concept needs to be evaluated under Australian conditions, since differences exist in the rate of reactivity of various sources of limestone in eastern Australia (Table 8). Theselimestone sources varied in particle size distribution and rate of reactivity, and the Southern Limestone "Microfine" had the greatest acid neutralising capacity of the limestone sources tested. Acid neutralising capacity was inversely proportional to particle size. These differences between limestone sources however, were not reflected in a change in glucose dynamics in sheep given a high grain diet (O'Connell & Kempton 1983). The effect of inclusion of sources of reactive and unreactive limestone on milk yield, milk composition, glucose dynamics and bodyweight change are currently being investigated in dairy cows at the Department of Agriculture, Wollongbar, N.S.W.

Evaluation of buffers such as limestone and the site of these buffers need to be defined to enable formulation of supplements which contain a buffer suitable to increase the efficiency of utilisatidn of the supplementary nutrients,

TABLE 8: Rate, of reactivity and particle size of several limestone sources in Eastern Australia (O'Connell & Kempton 1983).

Limestone Source	Type	Particle size (μm) % total 420	297	105	53	Reactivity (secs)
Attunga	Aglime	20	60	20		30
	Aglime Ground			10	90	167
	Stonedust				100	310
Southern Lime	Microfine				100	180
	F99/20			2	98	330
	Superfine		13	24	63	355
	Aglime	9	21	20	50	505
Control	$CaCO_3$				100	278

The role of limestone supplements under different dietary constraints must also be considered. For instance, the effect of limestone supplementation may be greater in cows grazing lucerne based pastures in which calcium availability is low due to high oxalate levels in the lucerne plant.

4. PARTITIONING OF NUTRIENTS

Under high levels of grain feeding, an increase in energy intake can change milk composition without increasing milk output (Sutton 1981). Under these conditions the additional energy intake is partitioned into body tissues. This phenomenon can be used to advantage in cows in late lactation to ensure that cows end a 300 d lactation in satisfactory body condition by using relatively cheap sources of concentrate Ørskov et al. (1981). In cows in early to mid lactation however, it is not desirable to have cows partitioning nutrients into bodyweight, since excessive weight loss during the first 60 d of lactation will cause extended calving to conception intervals.

With high levels of supplementary grain feeding the characteristics of grain fermentation predispose the animal to lipogenesis in the adipocytes, Concentrate diets are characterised by a fermentation pattern with a high ratio propionate: acetate in rumen fluid, and a considerable portion of the supplementary starch may also pass undegraded from the rumen and increase glucose supply to the animal. An increased uptake of glucose (from propionate and intestinal starch digestion) increases in insulin concentration which stimulates lipogenesis and the utilisation of acetate by peripheral tissues (Wahle and Elliot 1981). Also an increased propionate uptake promotes an increase in the circulating concentrations of methyl malonyl CoA (MeMal Co) which in turn inhibits the activity of fatty acid synthetase in the mammary gland. Under these conditions, high levels of concentrate in the diet promote tissue deposition and inhibit fat synthesis in the udder. The effect of hormonal mechanism on partitioning nutrients is discussed in more detail by Bauman and Currie (1980).

Supplementing high producing dairy cows with a source of bypass protein has been shown to increase milk yield (Clay and Satter 1979). A mechanism by which the bypass protein can increase milk yield is through the relationship between amino acid uptake from the intestines and circulating growth hormone (GH) concentrations (Oldham et al. 1978) and the GH status and milk yield (Hart et al. 1979). Growth hormone is also the main hormone involved in the maintenance of lactation.

Growth hormone also stimulates lipolysis in tissue adipocytes, promoting liveweight loss. For instance, in cows in early lactation and in negative energy balance, milk production, food intake and liveweight loss were increased in response to increasing levels of supplementation with a high quality protein, fishmeal (Ørskov et al. 1981). These results could be interpreted to support the hypothesis that in cows in negative energy balance an increased supply of undegraded dietary protein will increase blood GH concentration, increase tissue mobilisation and increase milk production.

With cows in positive energy balance, as occurs under high levels of concentrate feeding, the balance between protein absorbed and metabolisable energy intake may be imbalanced such that an increased intake of bypass protein may increase the utilisation of dietary energy and prevent partitioning into body tissues.

Little is understood about dietary manipulation to reduce partitioning of nutrients into body tissues. Possible alternatives may be to reduce the energy density of the diet by reducing the level of concentrate, which may reduce total milk output. Alternatively the level of roughage may be increased to reduce the energy density. A further manipulation may be to include higher levels of a bypass protein.

Sodium bentonite. Sodium bentonite is a diatomaceous earth with a high exchange capacity which enables binding with organic molecules such as ammonia, protein and amino groups, and enzymes such as urease and protease and various minerals and vitamins. Bentonite has a cation exchange capacity of between 80 to 150 mg/100 g and an anion exchange capacity of 23 mg/100 g (Grim 1968). Bentonite is used commercially in many pelleted and extruded ruminant rations and included in high grain rations at levels up to 4% to reduce the incidence of lacticacidosis.

Inclusion of 4% bentonite in a crushed wheat supplement given to dairy cows has been shown to increase voluntary intake of grain from 6.5 to 8.9kg DM/d, and increase butterfat (468 to 548 g/d) and protein (364 to 431 g/d), without an effect oh milk output (10.1 and 11.3 l/d). The additional energy from the increased grain intake was partitioned into bodyweight since liveweight change was -9.1 kg and +15 kg for the control and bentonite supplemented cows respectively (Rogers, unpublished).

In other studies cows given a high grain, fat depressing ration, inclusion of 5 and 10% sodium bentonite in the ration reduced energy and protein digestibility and yet increased milk output and butterfat content (see Table 9).

TABLE 9: Effect of supplementation of high grain diets with sodium bentonite on milk yield, milk composition and liveweight change. (Rundsig and Schultz 1970).

Level of bentonite %	Milk (l/d)	Fat %	Protein %	SNF %	Lwt change (kg/d)	N	Ca	P	Mg
						Balance g/d			
0	14.9	1.5	3.6	10.1	0.2	37	32	33	8
5	17.0	2.7	3.4	8.3	1.7	76	10	9	2
10	17.3	3.0	3.5	8.4	1.3	53	3	-3	2

In this study bentonite increased N retention in tissues which may reflect the effect of bentonite on ensuring more constant rumen NH_4^+ levels by holding the ammonium ion in a readily exchangeable form. The high faecal N output in cows receiving 5 and 10% bentonite however, indicates bentonite has the capacity to irreversibly bind N and protein. The lowered Ca and P balances in bentonite supplemented diets suggests bentonite may render Ca and P less available in the ration. Additional Ca and P may be needed when bentonite is added to the ration. Bentonite inclusion considerably increased bodyweight gain by 1.5 kg/d.

The inclusion of bentonite in low roughage/high concentrate rations maintains milk fat percentage (Bringe and Schultz 1969) through changes in rate of passage of digesta, an increase in rumen pH, and changes in the rumen fermentation pattern towards increased proportions of acetate and decreased propionate. The effect of including bentonite in high grain diets for dairy cows is therefore to increase butterfat output, and increase liveweight gain. The effect of bentonite on partitioning nutrients into bodyweight could be used to advantage with cows in late lactation, however, the effect may be a disadvantage to cows in early lactation. This is an area for further research.

Bentonite has also been used to complex with urea and prepared proteins to reduce the rate and extent of ruminal breakdown of these nitrogenous sources in ruminal fluid (Britton et al. 1975). This process has increased liveweight gain and feed efficiency in steers and lambs. Research is required therefore: to determine if bentonite may be given to dairy cows grazing lush green pastures to reduce the incidence of bloat, and to prevent the extreme fluctuations in rumen ammonia concentrations

5. PROTEIN TO ENERGY RATIO OF ABSORBED NUTRIENTS

In cows grazing lush pastures, it is generally considered that the yield of amino acids from microbial protein synthesised in the rumen is below the amino acid requirement for maximum milk production in early lactation (Oldham 1981). Supplementation strategies based on feeding cows sources of bypass protein have therefore been adopted to meet the shortfall between amino acid supply and requirements (Table 10).

These results highlight the large variation about observed responses to supplementing cows with a source of bypass protein. This large variation in response to feeding bypass protein is also being observed in practical feeding systems. Studies have shown however, that the response to supplementary protein is largely dependent on ME intake (Broster and Oldham 1981) and the variation observed may be related to differences in ME intake, and energy density of the diet. Comprehensive studies by Gordon and Forbes (1973) confirm there is a close response relationship between milk output and the level

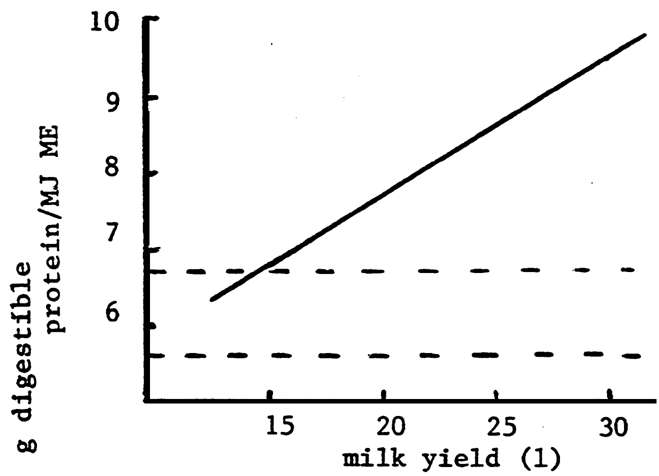
TABLE 10: Milk response of dairy cows to infusion of casein into the abomasum, or feeding formaldehyde treated casein to grazing cows.

Stage of lactation	Milk Yield (1)	Casein dose (g/d)	Percentage milk output	Response in milk protein output	Reference
Abomasal infusion studies					
Mid	22 (13-33)	170-2200	7 (-6to+22)	12 (-2 to + 31)	Clark 1975.
Mid	30	450	9	13	Clark *et al*.1977.
Early	20	250-750	18-27	34-60	Ørskov *et al*.1977.
Early	23	240-460	5	15	Konig *et al*.unpub.
Studies with Grazing cows					
Pasture type	15.0	1000	6	9	Minson, 1981.
Ryegrass/clover	16.6	1000	9	34	Rogers *et al*.1980.
Rhodes grass	12.7	1000	16	24	Stobbs *et al*.1977.

of intake of both ME and protein, and Paquay *et al*. (1973) calculated an optimal dietary ratio of protein in ME for milk production (Table 11).

The ARC calculations for protein and energy requirements of dairy cows for milk production are now based on the relationship between protein and energy intake and milk yield (see Fig. 3).

Figure 3: Relationship between protein/ energy requirements (g /MJ ME) and milk yield.



This relationship indicates that as ME intake is increased by supplementary feeding with high energy concentrates, the requirement for bypass protein can be increased to up to 10g/MJ ME in cows in early lactation. An increase in the protein-energy ratio of absorbed nutrients through supplementation with bypass protein has been shown to increase DM intake (Clay & Satter 1979).

In grazing cows therefore, in order to increase milk production by supplementing with high energy concentrates, attention must be paid to the balance between ME intake, and bypass protein supply The level of bypass protein feeding should be calculated on the basis of level of milk production, stage oflactation and level of ME intake, since overfeeding with bypass proteins is unprofitable.

Detailed research in grazing cows is necessary to define production responses to supplements of high energy, bypass protein, and various combinations of the two. Data are required to define if there is an optimal

TABLE 11: Optimal protein - energy ratios of absorbed nutrients in the diets of dairy cows according to stage of lactation. (from Paquay et al. 1973)

Months of lactation	Optimal P/E g digestible protein/MJ ME.
1-3	13.8
4-5	15.0
6-7	10.6
8-9	10.6
10+	8.1
Microbial N supply	8.1

protein-energy ratio in supplements which will reduce the substitution effect of high energy supplements. Data are also required to ascertain if increased levels of bypass protein in the diet can be used as a management aid to manipulate the partitioning of nutrients into bodyweight or milk.

CONCLUSION

The trend in the Australian Dairy Industry is toward feeding greater amounts of concentrated feed to increase milk yield and increase profitability. Areas in the nutrition and management of concentrate feeding that are emerging in the industry as potential problems requiring research investigation include:

1. Concentrate feeds substitute for pasture dry matter. Methods of feed processing and combinations of high energy feeds need to be investigated to develop high energy supplementary feeds as opposed to substitute feeds.

2. Legume pastures can contain high levels of soluble protein which support high levels of NH_3-N in ruminal fluid of grazing cows. High NH_3-N concentrations have been implicated in ruminal stasis, and fertility problems. It may be possible to use compounds such as sodium bentonite to reduce fluctuations about rumen NH_3-N concentrations.

3. High levels of concentrate feeding apparently inhibit amylase activity in the intestines and reduce starch digestion. A source of limestone in the diet has improved starch digestion under some pasture conditions.

4. High levels of concentrate feeding predispose cows to partition energy into body tissues as opposed to milk synthesis. Means to prevent partitioning of nutrients into body tissues, and yet maintain milk production are required. The effect of bypass proteins on circulating growth hormone concentrations, and bodyweight loss require further research.

5. Supplementary feeding strategies require that cows are given nutritionally balanced diets to achieve high levels of milk production. In formulating these diets, the aim must be to maximise the production of high energy feeds at least cost on farm, to maximise the utilisation of these feeds, and to supplement the diet as required to provide complete diets. The bottom line is to maximise income above feed costs.

REFERENCES

BARTEY, E.E. and DEYOE, C.W. (1981). In "Recent Developments in Ruminant Nutrition" pp.99414 (eds. W. Haresign & D.J.A. Cole) Butterworths. U.K.

BATH, D.L. and BENNETT, L.F. (1980). J. Dairy Sci., 63: 1379.

BAUMAN, D.E. and CURRIE. W.B. (1980). J. Dairy Sci., 63: 1514.

BINES, J.A. (1979). In "Feeding Strategy for the high yielding dairy cow" (eds. W.H. Broster & H. Swan) pp.23048 (Granada Publishing Ltd, St. Albans.
BLAXTER, K.L. and WILSON, R.S. (1963). Anim Prod. 5: 27-42.
BRINGE, A.N. and SCHULTZ, L.H. (1969). J. Dairy Sci. 52: 465.
BRITTON, R., COLLING, D. and KLOPFENSTEIN, T. (1975). Feedstuffs. 80: 9.
BROSTER, W.H. and OLDHAM, J.D. (1981). In "Recent Developments in Ruminant Nutrition" pp.31 (eds. W. Haresign & D.J.H. Cole) Butterworths. U.K.
CHOPPING, G.D., DEANS, H.D., SIBBICK. R., THURBON, P.M. and STOKOE, J. (1976). Proc. Aust. Soc. Anim. Prod. 11: 481.
CLARK, J.H. (1975). J. Dairy Sci., 58: 1178-1179.
CLARK, J.H., SPIRES, H.R., DERRIG, R.G. and BENNIK, M.R. (1977). J. Nutr. 107: 631-644.
CLAY, A.B. and SATTER, L.D. (1979). J. Dairy Sci. 62: 75.
COWAN, R.T., BYFORD, I.J.R. and STOBBS, T.H. (1975). Aust. J. Exp. Agric. Anim. Husb. 15: 740.
COWAN, R.T., SCHACKEL, D., O'GRADY, T. and BYFORD, I.J.R. (1976). . Proc. Aust. Soc. Anim. Prod. 11: 485.
DUCKER, M.J. (1980). In "Feeding Strategies for Dairy Cows". (Eds. W.H. Broster C.L. Johnson and J.C. Taylor). pp.1-11.
FERGUSON, K.A., HEMSLEY, J.A. and REIS, P.J. (1967). Aust. J. Sci. 30: 215.
FRENCH, D. (1973). J. Anim. Sci., 37: 1048.
GOERING, H.K. and WALDO, D.R. (1974). Proc. 1974 Cornell Nutr. Conf. p.25.
GORDON, F.J. (1981). In "Recent Developments in Ruminant Nutrition" pp.17 (eds. W. Haresign & D.J.A. Cole) Butterworths. U.K.
GORDON, F.J. and FORBES, T.J. (1973). cited by Broster & Oldham (1981).
GRIM, R.E. (1968). Clay Mineralogy. McGraw Hill Book Co. New York.
HART, I.C., BINES, J.A. and MORANT, S.V. (1979). J. Dairy Sci., 62: 270.
HAGEMEISTER, H., LUPPING, W. and KAUFMANN, W. (1981). In "Recent Developments in Ruminant Nutrition" pp.31. (eds. W. Haresign & D.J.A. Cole) Butterworths.U.K
KEMPTON, T.J. (1982). Wld. Rev. Anim. Prod. 18: 7.
KEMPTON, T.J. (1983). Anim. Feed Sci. Technol. (submitted) .
KING, K.R. and STOCKDALE, C.R. (1973). Aust. J. Exp. Agric. Anim. Husb. 20: 537.
LEAVER, J.D. (1981). In "Recent Advances in Animal Nutrition" pp.71-80 (eds. W. Haresign & D.J.A. Cole) Butterworths. U.K.
McLINTOCK, A.E. (1982). Aust. Assoc. Anim. Breeding and Genetics. p.132.Brisbane
MINSON, E.J. (1981). J. Agric. Sci. (Camb.) 92: 239.
NIX, J. (1980). In "Feeding Strategies for Dairy Cows". (Eds. W.H. Broster, C.L. Johnson and J.C. Taylor) pp.1-15.
O'CONNELL, P.J. and KEMPTON, T.J. (1984). Proc. Nutr. Soc. Aust. (submitted)
OLDHAM, J.D. (1981). In "Recent Developments in Ruminant Nutrition" pp.49 (eds. W. Haresign and D.J.A. Cole) Butterworths. U.K.
OLDHAM, J.C., HART, I.C. and BINES, J.A. (1978). Proc. Nutr. Soc. 37: 9A.
ØRSKOV, E.R., GRUBB, D.A. and KAY, R.N.B. (1977). Br. J. Nutr. 38: 397-405.
ØRSKOV, E.R., REID, G.W. and TART, C.A.G. (1981). Br. Soc. Anim. Prod. 32: 361.
ØRSKOV, E.R., HUGHES-JONES, M. and McDONALD, I. (1981). In "Recent Developments in Ruminant Nutrition" p.17. (eds. W. Haresign & D.J.A. Cole)Butterworths.U
ØRSKOV, E.R., SOLIMAN, H.S. and MacDEARMID, A. (1978). J. Agric. Sci., Camb. 90: 611-615.
PAQUAY, R., GODEAU, J.M., de BAERE, R. and LOUSSE, A. (1973). J. Dairy Res. 40:32
ROGERS, G.L., PORTER, R.H.D., CLARKE, T. and STEWART, J.A. (1980). Aust. J. Agric. Res. 31: 1147.
RUNDSIG, R.B. and SCHULTZ, L.H. (1970). J. Dairy Sci. 53: 888.
SCOTT, T.W., BREADY, P.J., ROYAL, A.J. and COOK, L.J. (1972). Search 3: 170.

STOBBS, T.H., MINSON, D.J. and McLEOD, M.N. (1977). J. Agric. Sci., (Camb) 89: 137.

STORRY, J. and BRUMBY, P. (1979). Big Farm Man. Westminster Press.

SRISKANDARAJAH, N., ASHWOOD, A. and KELLAWAY, R.C. (1980). J. Agric. Sci., (Camb). 95: 555.

SUTTON, J.D. (1981). In "Recent Advances in Animal Nutrition". pp.35-48. (ed. W. Haresign) Butterworths. U.K.

THOMAS, G., MATTHEWS, G. and CHAPMAN, H. (1980). In *'Dairy Production Research Report 1980", Department of Agriculture, Victoria pp.69-71.

TRIGG, T.E. (1983). In "Recent Advances in Animal Nutrition" (ed. D.J. Farrell) University of New England Publishing Unit.

WAHLE, K.W.J. and ELLIOT, J.M. (1981). Proc. 1981 Cornell Nutrition Conference.

WALDO, D.R. (1973). J. Anim. Sci. 37: 1062.

. WHEELER, W.E., NOLLER, C.H. and WHITE, J.C. (1981). J. Anim. Sci. 52: 882.