

MILK PRODUCTION, BODY CONDITION SCORE AND REPRODUCTION RESPONSES TO SUPPLEMENTATION IN GRAZING DAIRY COWS

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Summary

- Replacing pasture with concentrates will not improve milk production.
- To be profitable, supplements must be used in situations where cows would otherwise be hungry.
- When offered in feed deficit situations, and when fed to high genetic merit dairy cows, each kg of concentrate will result in between 1.0 and 1.25 kg milk.
- Supplements do not influence BCS loss during the first six weeks of lactation; thereafter concentrate supplements will reduce BCS loss and increase the rate of BCS gain.
- Concentrate supplementation has minimal impact on reproductive success; unless substitution rate is low (ie, cows would be otherwise severely underfed).
- The decision to feed supplements should be based on the economics of the milk production response. Responses less than this are unlikely to improve reproduction, health or other less tangible returns.

Introduction

As the liberalisation of world trade continues and the international competition for markets accelerates, farmers must consider the competitiveness of their production systems. A concerted effort must be made to understand the strengths and weaknesses of various systems of production, and comparisons made of the performance of the component pieces of the business to international standards or benchmarks.

Notes:

The global competitive advantage of New Zealand agricultural produce depends on improvements in the output per land area and labour unit, while maintaining or reducing the unit cost of production. Cost of production is hugely influenced by feeding strategy. Wales *et al.* (2006) reported that feed costs now comprise 45 to 60% of total costs on irrigated dairy farms in Northern Victoria and Dillon *et al.* (2005) reported a 66% increase in the cost associated with supplementary feed in Southern Australia between 2000 and 2003. In comparison, farm gate receipts declined 10% during the same period.

Farmers all over the world must consider the use of supplementary feeds judiciously, only using them when a true economic benefit is likely.

Cost of production across dairying systems

In a recent review of the profitability of grazing systems, Dillon *et al.* (2005) examined the system of milk production in 10 countries, and could account for 88% of the variation in the cost of milk production, by accounting for the proportion of grazed grass in the diet. This is a far more comprehensive way of examining the cost of production that can be attributed to non-pasture feeds, as it accounts for additional 'system' costs such as labour to milk additional cows, or repairs and maintenance and depreciation of feeding equipment, which would not be accounted for in more simple marginal analyses. They reported a negative linear association ($r^2=0.78$) between the proportion of grazed grass in the diet and the cost of milk production, with the cost of milk production decreasing 4.9 cents/kg milk for every 10% increase in the proportion of grazed grass in the diet.

However, a closer look at the data indicates a non-linear relationship ($r^2=0.95$; Figure 1). These data indicate that the increased cost of milk production with increasing supplementation declines when very high levels of supplements are offered (>50% of the diet), probably because the greater capital and labour requirements associated with such intensive operations are similar to those required for complete confinement dairies.

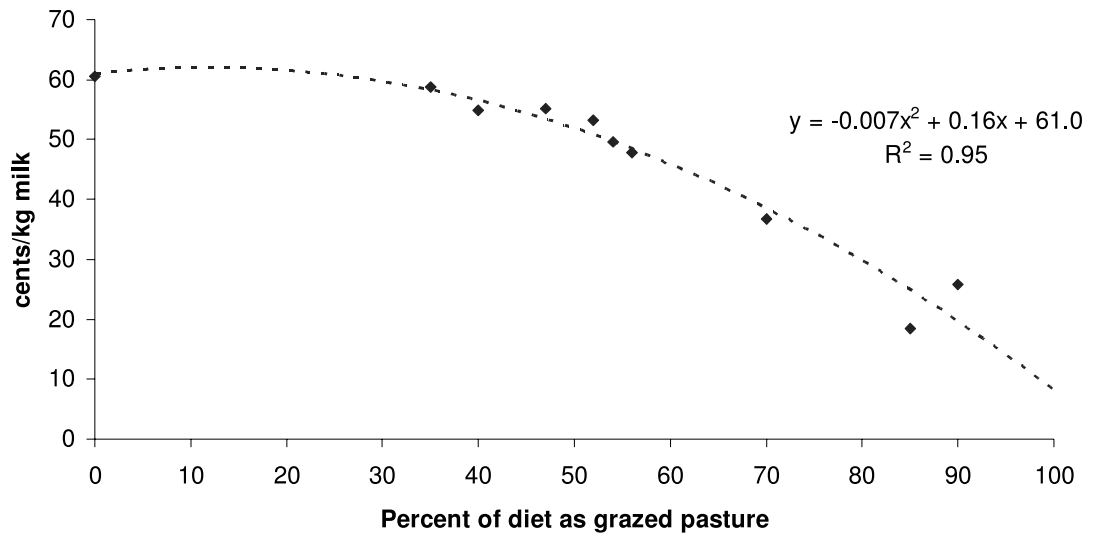


Figure 1: The relationship between the proportion of grazed grass in the diet and the total cost of milk production (Adapted from Dillon et al., 2005)

However, and more importantly, the data also suggest that incremental increases in supplement use in the biological range common in New Zealand (if it replaces grazed pasture) have an even greater effect on the cost of milk production than was predicted by the linear contrast reported earlier.

Fitting a linear function to the data where grazed pasture constitutes 50% of the diet or greater, indicates an 8.2 cents/L increase in the cost of milk production, for every 10% reduction in the proportion of grazed grass in the diet ($r^2=0.93$). If we were to assume a substitution rate of 100% (ie, concentrates replacing pasture), a 10% increase in supplement input (ie, a 10% reduction in the proportion of grazed grass in the diet) must increase milk production by at least 20 to 25% (assuming \$4.10/kg MS and 8.5% solids) to just break even. Assuming that a cow consumes 5,000 kg DM/year and produces approximately 5,000 L milk/year (Holmes *et al.*, 2002), increasing supplementation from 500 kg (90% of diet as grazed pasture) to 1 tonne of concentrate (80% of diet as grazed pasture), one would have to increase milk yield by 1,000 L/cow, or a response to concentrates of approximately 2 L milk/kg concentrates. These figures

Notes:

are consistent with recent estimates in the U.S. (Bullock, 2006), where if milk price is not at least 2.5 times the price of concentrates (a large variable in the cost of milk production) farms begin to lose money and market forces (and government intervention schemes) react to increase milk price. For this reason, the current interest in using grain for bio-fuel is a major threat to dairy industries heavily reliant on concentrates.

Rarely, if ever, have such large responses (~2.0 L milk/kg concentrate) been published in controlled research experiments, even when cows are severely underfed. Such a response to concentrates would only be possible if all supplement energy consumed was additional to what cows were already eating (ie, no substitution), there were minimal negative associative effects between concentrate supplementation and forage digestibility, and all energy was partitioned into milk production. In practice, losses in feeding, the substitution of supplement for pasture, reduced feed digestibility, and the partitioning of energy into live weight gain or the maintenance of additional cows result in much smaller responses.

On a more positive note, a substitution rate of 1 for 1 is also highly unlikely, except in very low milk potential cows that are very well fed on pasture, and so there is potential for concentrate supplements to be used profitably for milk production, as is indicated in response rates identified under farm systems research. However, the profitable use of supplements in dairy systems requires an understanding of the factors affecting responses to supplements, providing the farmer with reasonably accurate estimates of likely milk and non-milk responses that will be achieved.

Factors affecting response to supplements

Energetic theory suggests that 65 MJ ME are required to synthesise 1kg milksolids (MS; fat + protein). Logically therefore 1MJ ME should result in an additional 15g milksolids, or 1kg DM of supplement containing 13 MJ ME (i.e. 1 kg DM maize grain) would produce approximately 200g MS (approximately 2.5 L milk). This is the maximum possible response to extra feed, and assumes that all the energy is consumed, is additional to the pasture energy consumed and is converted into milk. Actual responses are much less than this.

For example, average responses reported in a review of short-term experiments (Penno, 2002) were 4.1g MS per MJ ME of supplement (~0.7 L milk/kg concentrate DM) or approximately 27% of the theoretical response. However, supplemented cows reduced their intake of pasture and gained additional live weight. The energy partitioned into live weight (approximately 33% of supplement energy) plus the reduction in pasture energy consumed (approximately 35% of supplement energy) account for 95% of the differences between the maximum theoretical milk production response and those found in these short term studies. An approximate “energy flow” is illustrated in Figure 2.

Responses to supplements depend on three main factors (assuming a constant supplement quality – i.e. concentrates).

1. physical losses of supplement
2. substitution of supplements in lieu of pasture
3. partitioning of nutrients

and these determine the likely milk production, fertility and health response to concentrates, and the profitability of supplement use on dairy farms.

Physical losses of supplement

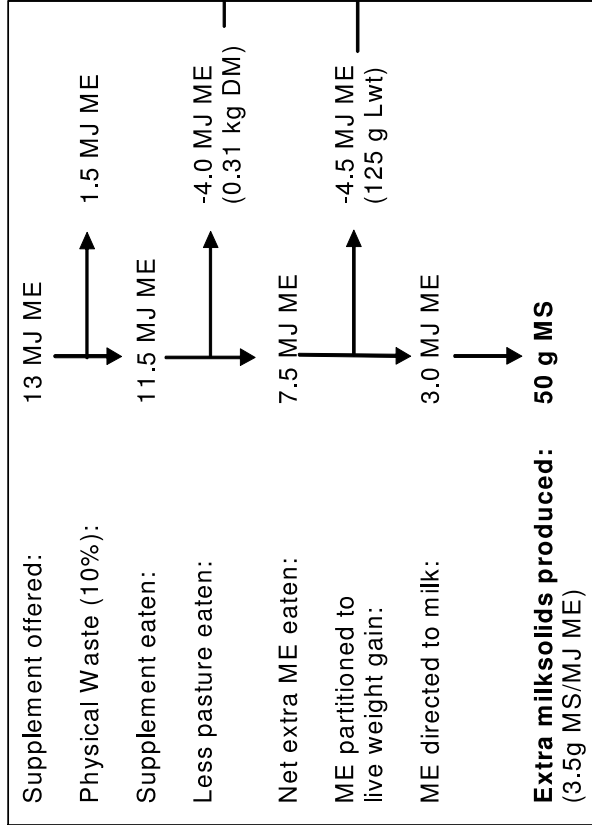
Although this is an important aspect of supplementary feeding, full discussion of this topic is beyond the scope of this paper. Large losses of energy can and do occur at all stages - during harvest (~10%), transport (5%), storage (10-20%) and feeding-out (e.g. 10 to 50%). For silages in particular, the losses during conservation and feeding-out (including re-fermentation at the face) can be large. Great care is required to minimise these losses, which reduce the amount of supplement available, and increase the cost per kg DM of the feed that is finally consumed.

Substitution of supplements in lieu of pasture

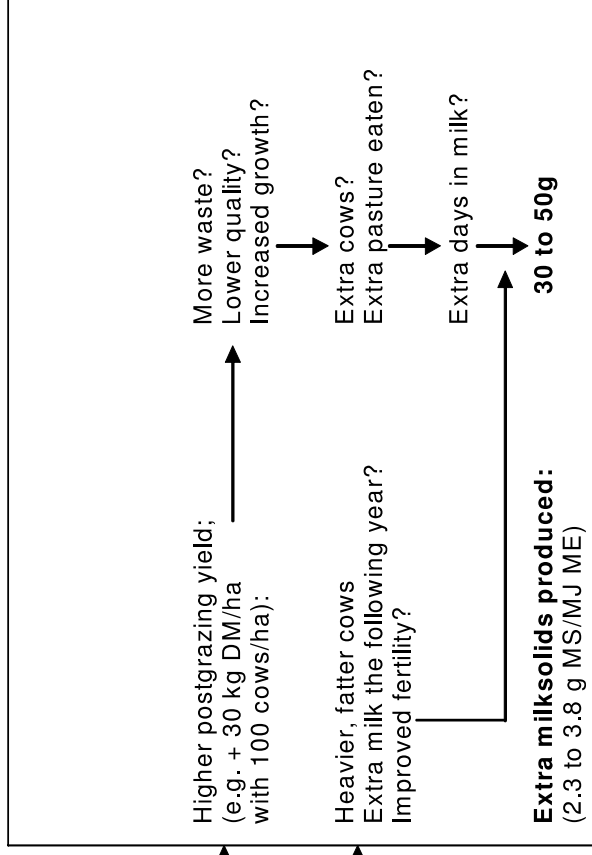
Replacing pasture with supplements in an attempt to improve nutritive value of the diet does not necessarily improve daily milk production (Carruthers *et al.*, 1997; Roche *et al.*, 2006b). Supplements will increase animal performance only by the extent to which they result in an increase in total energy consumed. When grazing cows are fed supplements, pasture dry matter intake (PDMI) declines; therefore, increases in feed offered will not result in equal increases in daily PDMI, even in feed-restricted cows, and the theoretical maximum response to the energy offered is rarely (if ever) achieved.

Notes:

SHORT-TERM: Immediate responses



LONG-TERM: Carry-over responses



TOTAL RESPONSE TO SUPPLEMENTS

80 to 100 g MS/kg concentrate DM
(1 to 1.25 kg milk/kg concentrate DM)

Figure 2: Immediate and longer-term responses to 1 kg concentrate DM fed (Source: Holmes and Roche, in press).

A considerable amount of research has been undertaken over the last thirty years into substitution rate, with remarkably consistent results over a wide range of experimental conditions (Dulphy, 1978; Grainger & Mathews, 1989; Penno, 2002). The substitution rate (**SR**; kg decline in pasture intake/kg supplement) of supplements for pasture can be predicted simply from the equation (Penno, 2002): Substitution rate = $0.31 \text{ PDMI} - 0.50$ where PDMI is Pasture Dry Matter Intake (measured as kg pasture eaten/100 kg Live weight).

Therefore substitution rate increases with greater pasture dry matter intake but is less in bigger (higher genetic merit) cows. For example if a cross-bred cow (450kg) consuming 16kg DM pasture eats 2kg DM supplement, she will reduce her pasture intake by approximately 1.25kg DM of pasture (SR of 62%) and DMI will only increase by 0.76kg DM. This would probably result in a marginal milk production response of 0.55 kg milk/kg concentrate DM. However, if that cow was only able to consume 10kg DM of pasture, SR would be only 20%, and total intake would increase by 1.6kg DM if supplemented with 2kg DM concentrates (approximately 1.25 L milk/kg concentrates).

At any particular pasture intake, heavier cows, or cows with greater milk potential, have lower substitution rates. Therefore substitution rate is generally highest and milk production responses lowest:

- at high pasture allowances
- with low quality supplements and/or
- when supplements are fed to low energy demanding dairy cows.

However, as discussed earlier, supplements should only be fed when pasture allowance is lower than cow requirements (because of insufficient pasture growth or planned reduced area/cow). Where these principles have been observed, annual substitution rates in farm system experiments over a whole year were 0.22 and 0.53 at medium (0.84 t DM/cow) and high (1.7 t DM/cow) levels of concentrate feeding in Australia (Fulkerson, 2000), and 0.28 with about 1 t DM fed per cow as maize silage, maize grain or a partial mixed ration in New Zealand (Penno, 2002). In such situations, responses of 1.0 to 1.2 kg milk/kg of concentrates is possible, and providing that concentrate price (\$/kg DM) and associated costs of feeding them are less than milk price (\$/L), farmers can improve profitability through strategic use of such supplements.

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Partitioning of nutrients

The mobilisation of body tissue in early lactation and the amount of energy consumed that is partitioned towards gaining BCS in mid- and late-lactation can influence the apparent response of cows to additional supplement in short-term experiments. Genetic selection for milk production has led to a cow with increased growth hormone production, and consequently a greater drive to produce milk at the expense of body tissue. (Holmes, 1988; Veerkamp and Emmans, 1995; Roche and Lucy, 2004). The introduction of genetics from intensive feeding systems into pasture-based systems has exacerbated this body condition loss (Roche *et al.*, 2006a).

These “modern” cows (e.g. USA Holstein-Friesians) mobilise more condition in early lactation and partition less towards gaining body condition in late lactation, resulting in thinner cows at the end of lactation (Roche *et al.*, 2006a). A simple calculation suggests a greater short term milk production response to concentrates from these ‘modern’ cows, than from cows that do not have this predisposition (Kolver *et al.*, 2005). However, such a system would not be sustainable, because the resultant thin cows require additional supplement while dry, to regain a suitable calving BCS. Therefore, genetic selection has altered the stage of the lactation when feed must be offered to achieve increases in BCS, but has probably not altered the amount of feed required to regain body condition.

Feeding level does affect BCS, especially later in lactation. However in early lactation, rate of loss of BCS is not affected by severe underfeeding (Roche *et al.*, 2005) nor by feeding concentrates (Figure 3; Roche *et al.*, 2006a, b). These results are consistent with physiological evidence (Roche *et al.*, 2006a; Roche & Lucy, 2004) that suggests that the genetic drive to mobilise body tissue after calving overrides any effects of nutrition. Use of North-America genetics exacerbates this predisposition to BCS mobilisation (and failure to replenish tissue stores), with concentrate feeding levels in excess of 3kg DM/cow/day required to alter the patterns of BCS loss and gain (Roche *et al.*, 2006a). Such cows are less likely to be suited to seasonal-calving pasture-only systems with its lower potential daily feed intakes (Buckley *et al.*, 2005) and often tend to have poorer fertility in such systems than other genotypes and breeds.

Response to supplements

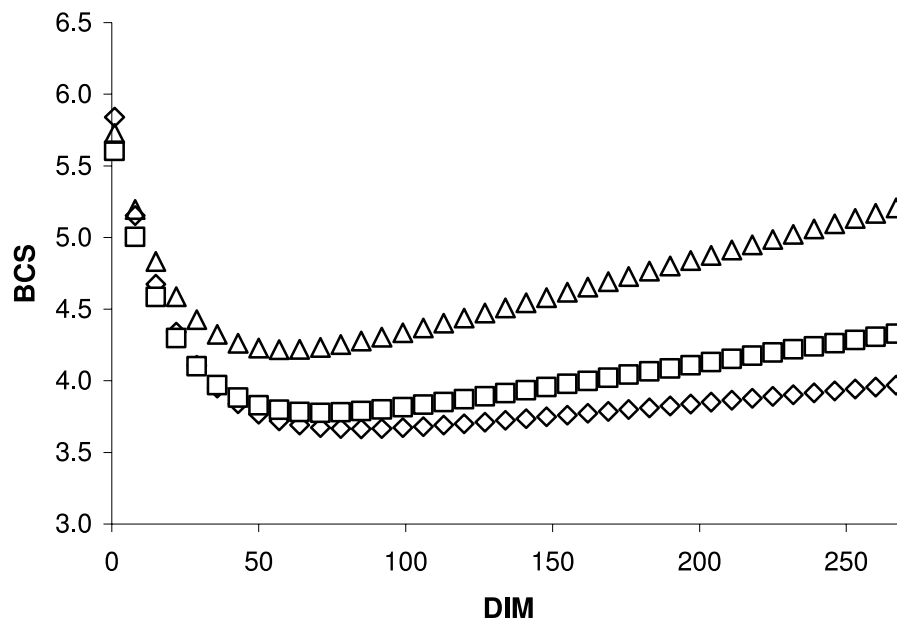
Milk production responses

The short-term milk production response to supplement fed is dependent on the substitution rate, the quality of the supplement relative to the grazed forage, and the proportion of additional energy that is directed into milk relative to body tissue gain. The full (long-term) response to supplements therefore depends on the short term-response, and on the final fates of the extra live weight gained and the substituted pasture. If some of these are utilised for milk

production later in the current, or even the next lactation, then the final total response to the extra energy eaten will be greater than the reported short term response (Figure 2).

The system will show larger responses to extra feed if its energy demand is higher than its energy supply (ie, if it needs the extra feed). Extra dietary energy can produce more milk by,

1. increasing milk yield per day
2. increasing the number of days in milk, or
3. increasing the number of cows grazed per hectare (or by combinations of all three).



- ◇ - Pasture
- - Pasture + 2.9kg DM concentrates/day;
- △ - Pasture + 5.7kg DM concentrates/day

Notes:

Figure 3: Concentrate supplementation did not affect the rate of body condition score (BCS) loss in early lactation, but reduced days in milk to the point of lowest BCS, and increased the rate of BCS gain. Body condition score was measured on a 1 to 10 scale (Source: Roche et al., 2006a).

If supplements are used, option 1 is likely to be associated with a high substitution rate, because of the higher feeding level required. Option 3 will cause an increased partitioning of dietary energy into maintenance of the extra cows, which will tend to reduce the marginal milk response towards the value of the herd's gross feed conversion efficiency; while option 2 could theoretically minimise the extent of partitioning into live weight gain or into maintenance. Experimental comparisons in New Zealand reported that feeding 1 t DM/ha as supplement allowed an increased stocking rate of 0.2 to 0.25 cows/ha and an 80 to 100 kg increase in MS/ha (Macdonald, 1999; Penno et al., 1999; Thomson et al., 1997; Dalley et al., 2005). Similar differences between commercial farms that did or did not use extra feeds, were also reported by Silva-Villacorta et al. (2005). Maintenance of the extra 0.2 to 0.25 cow/ha would have required about 40% of the energy supplied by the 1t of extra DM.

If supplements are used strategically during short periods of feed deficit, after which cows graze high quality pasture, larger responses (up to 1.5 kg milk/kg DM) may be obtained. However these responses are less usual, and should be regarded as the exception rather than the rule. When supplements are used in situations where cows would otherwise be underfed (ie, if post-grazing residuals are likely to be less than previous rotations), responses in the range of 80 to 100g MS/kg concentrates DM (approximately 1.0 to 1.2 L milk/kg concentrates DM) can be expected from modern high producing dairy cows.

Measured milk production responses (per unit of energy) are similar irrespective of the supplement, provided they are given in similar situations. For example Penno *et al.*, (1999) and McGrath *et al.*, (1998) reported 7.5 to 8g MS/MJ ME for maize grain, maize silage, a balanced ration, or additional pasture from nitrogen fertiliser. Therefore the decision to purchase energy supplements should be based on the cost per MJ ME in the supplement.

Reproduction

Despite the beneficial effect of energy supplements on reducing the period when cows are losing BCS (Roche et al., 2006a), there is little evidence that supplementary feeding will enhance any of the measures of reproductive success in cows otherwise well fed on high quality pasture (Buckley *et al.*, 2000; Horan et al., 2003; Roche et al., 2007). Although Kolver *et al.*, (2002) showed a positive effect of a total mixed ration on the fertility of North American-type Holstein-Friesians, there was no effect of supplementing the same strain with either 2.9 or 5.7kg concentrate DM/cow/day throughout lactation (Kolver *et al.*, 2005).

Fulkerson *et al.*, (2001) reported a beneficial effect of concentrate supplementation on postpartum anoestrus interval (**PPAI**) and submission rate in high genetic merit dairy cows, but not lower genetic merit cows. However conception rate declined from 48% to 36% and 21% as concentrate supplementation increased from 0.34 to 0.84 and 1.71t DM/year, respectively.

This effect of concentrates on the PPAI is consistent with results presented by Burke *et al.*, (2006), who found that grain supplementation reduced the period to first oestrus by 8 days when compared with cows consuming an equal amount of energy from pasture and pasture silage. However, there was no beneficial effect of concentrates on conception rate, consistent with the previous work of Fulkerson *et al.*, (2001).

Nutrition can affect reproduction through its effect on calving condition score. Cows calving at BCS 4 compared to 5 (10-point scale) have an extended PPAI (~8 to 10 days), reducing the potential number of breeding events the cow can undergo, particularly for later calving cows (Burke *et al.*, 2005; 2006) and increasing the Vet, Med and AI costs (increased CIDR usage and veterinary attention). However, contrary to popular dogma, feeding cows concentrates in early lactation (the first 6 to 7 weeks of lactation) does not affect BCS loss and so is not likely to affect conception rate. Similarly, concentrate supplementation has only a small effect on condition score gain in modern high genetic merit dairy cows, and is unlikely to positively impact on the reproductive success of cows already well fed on pasture. Roche *et al.* (2007) estimated that 10 kg concentrates/cow/day would be required to improve reproductive success by 1% unit over a 12 week breeding season.

In comparison, grossly underfeeding cows in early lactation can prolong periods of anoestrus (McDougall *et al.*, 1995; Macdonald, 1999; and McCallum *et al.*, 1994), although short periods of underfeeding (5 weeks) did not affect PPAI (Burke *et al.*, 2005). Supplements could be used effectively in both of these situations (ie, to increase BCS precalving or to meet cow demand in early lactation). There is little information available on the effect of a feed restriction during the mating period on pregnancy rate. However, the accentuated negative energy balance caused by a feed restriction would be expected to reduce fertility. Nevertheless, use of supplements in such situations would be expected to result in an economically viable increase in milk production.

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Conclusions

Replacing pasture with supplements will neither increase milk production nor benefit cows from a health or reproduction point of view. However, supplementing cows that would otherwise be underfed (ie, if current postgrazing residual is less than the previous postgrazing residual), total responses in the range of 7 to 8 g MS/MJ ME can be expected. This is equivalent to 1 to 1.25 L milk/kg concentrates. The size of this response will be dependent on the size of the feed deficit. Concentrate supplementation does not reduce the rate of weight loss in early lactation, although the period of weight loss can be reduced by approximately 3 days/kg concentrates. Except in extreme feed deficit situations, concentrate supplementation is unlikely to improve fertility.

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