Supplement use and making money – the devil is in the detail

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Key messages

- Before any decision is made to purchase and feed supplements, total costs and benefits need to be considered
- There is no advantage to replacing good quality pasture with an alternative feed source or "balancing pasture"; therefore, supplements should only be used to provide energy when there is insufficient pasture available or eaten.
- Possible benefits of feeding supplements include:
  - increased milk revenue and body condition at calving,
  - improved health and reproduction, if energy is limiting,
  - reduced overgrazing during a feed deficit.
- International datasets indicate the total costs associated with the use of supplements can be 50% more than the cost of purchasing the feed. Total costs include:
  - price of supplement,
  - associated costs such as supplement wastage, capital, fuel/energy, labour, repairs and maintenance,
  - non-associated costs
- If feeding supplements results in high grazing residuals, this wasted feed and the reductions in future pasture growth and quality must be considered.

Introduction

"Supplements" are defined as any feed type provided in addition to grazed pasture and are incorporated into pasture-based systems for any of numerous reasons. Some reasons are strategic, such as system intensification or growing a business within fixed constraints, whereas others are tactical or operational, and involve day-to-day decisions on what type and how much of a supplement should be used. Although farmers have many goals, this paper focuses on the tactical use of supplements, with profit as the core driver of business decision-making. The cost of production/kg milksolids is the primary driver of operating profit/ha that is under the farmer's control, with all other variables either outside the farmer's control (i.e. milk price, feed price) or having less influence on a farm's operating profit/ha (i.e. milksolids yield per cow or per ha). It is, therefore, imperative to understand the effect of supplementary feeding on operating expenses, and examine the benefits and costs of supplement use.

Reason to feed supplement	Factors that affect profitability	
	Costs	**Benefits**
Increase dry matter intake/milk yield	Supplement[1] Wasted pasture[2] Pasture quality[3]	Milk production
Increase protein:fat ratio	Wasted pasture Supplement	Milk composition
Alter milk urea	Supplement Wasted pasture Pasture quality	Reduce expensive protein supplements
Balance pasture	Supplement Wasted pasture Pasture quality	
Balance crops	Supplement	Animal health
Improve reproduction	Supplement Wasted pasture Pasture quality	Improved reproduction
Prevent body condition loss in early lactation	Supplement Wasted pasture Pasture quality	Milk production BCS at mating
Increase body condition in late lactation	Supplement	Milk production BCS at calving
Increase body condition during the dry period	Supplement	BCS at calving
To fill a feed deficit	Supplement	Milk production Reproduction Prevent over-grazing Reduced BCS loss
Push out the grazing round	Supplement	Pasture grown Annual pasture cover
Maintain intake in adverse weather	Supplement Wasted pasture Pasture quality	Milk production Reduced BCS loss
Mineral supplementation	Supplement Wasted pasture Pasture quality	Animal health
Cow flow	Supplement Wasted pasture Pasture quality	Time, labour, stress
Have it contracted!!	Supplement Wasted pasture	Milk production

	Pasture quality	

Table 1. Typical reasons given for feeding supplements within pasture-based farm systems and the associated costs and benefits.

[1]The total cost of feeding the supplement

[2]Reduced pasture eaten through wasted pasture and reduced pasture recovery if post-grazing residuals are greater than 1500 - 1600 kg DM/ha (7-8 clicks on RPM)

[3]Reduced future pasture quality if residuals are greater than 1500-1600 kg DM/ha (7–8 clicks)

Common reasons for the tactical use of supplements and potential costs and benefits are provided in Table 1. In many cases, the reason for incorporating supplements is justified at an animal level; however, this will not always translate to positive outcomes at a systems level and, hence, will not result in improved profitability. The biggest challenge is to continually question "why" feeding supplements is desirable and then ensure that the decisions on "when", "how much" and "what type" of supplement to use are profitable ones. This means taking into consideration the total cost of feeding the supplement and comparing this cost with the benefits at both an animal and farm systems level. This paper describes some of the more common tactical reasons that supplements are incorporated into a pasture-based system and whether or not these reasons can be justified economically. It details the additional factors that need to be considered to ensure the decisions made are profitable.

What are the costs of feeding a supplement?

Supplement price and associated costs

It is difficult to separate the costs of tactically feeding cows a supplementary feed from the strategic cost of system intensification (capital), wherein the cost of feeding infrastructure and machinery must also be considered. Many people refer to "Margin over Feed" or "Margin over Feed and Fertiliser" as ways of accounting for the cost of inputting a supplementary feed without incurring capital cost. However, this assumes that the only cost of feeding is that of the feed itself and ignores associated costs such as fuel/energy, repairs and maintenance, and labour; these are costs that most people accept also increase (at least per ha) when supplementary feed is offered. Where these associated costs have been considered, they equate to between 5 and 10% of the actual cost of the feed. For example, the DairyNZ Feed Cost Calculator estimates an additional cost of feeding supplement of 2.7 c/kg for in-shed feeding, 3.0 c/kg for feeding palm kernel expeller (PKE) in a trailer in the paddock, 4.5 c/kg for feeding silage on a feed pad, and 5.7 c/kg for silage fed in the paddock.

If, however, supplements are already offered, then the cost of adding additional supplements must surely be negligible? After all, the labour and capital infrastructure is already in place. The only change is the amount of supplement that is being fed; therefore, the cost of this decision is the marginal cost of the feed! This logic, although seemingly reasonable, is flawed. An analysis of the UK National database in 2012 (DairyCo, 2013) highlighted an increase in total farm costs of £1.62 for every £1 spent on imported feeds (i.e. forages and concentrate feeds). Consistent with this, an analysis of four years of data from more than 2,700 farms in Ireland highlighted that, on average, the total cost of production increased €1.52 for every €1 spent on purchased feed (Ramsbottom et al., 2014). In the Irish dataset, virtually every cost (variable and fixed) increased with increased feed use.

It is important to note that, for historical reasons, all of the farming systems in those countries already possess the capital infrastructure for housing and feeding cows and, yet, their total costs increase by 50-60% more than the feed cost when additional feed is fed. There is a message from these international datasets; the total cost of feeding a supplement is much more than the cost of the feed. However, robust analyses of New Zealand data are required to determine what the true cost is for New Zealand dairy farmers.

Cost of wasted pasture

The addition of supplements into a pasture-based system will increase total dry matter intake (DMI); however, for every kg DM supplement that is added into a pasture-based system, some pasture will be left behind. This phenomenon is known as substitution, and is characterised by a decrease in grazing time of approximately 12 min/kg DM supplement and, consequently, a decrease in pasture utilisation (Bargo et al., 2003; Sheahan et al. 2011). Substitution can be negative (pasture wasted) or positive (pasture spared). If it is negative then it contributes to the cost of feeding the supplement. The primary driver for substitution is how hungry the cow is, or alternatively, how much pasture remains uneaten when the cows leave the paddock: the post-grazing residuals. When residuals are greater than 1500 – 1600 kg DM/ha (7 – 8 clicks on the RPM), then pasture is being wasted and the cost of not utilising this pasture must be included in the cost of feeding supplement. In addition to the wasted pasture that is left behind, under-grazing or leaving high grazing residuals can reduce future pasture growth and quality (Chapman et al., 2014).

What are the benefits of feeding supplement?

Supplements can increase milk yield and milk value

One of the primary reasons that supplements are incorporated into a pasture-based system is to increase DMI, with the ultimate aim of producing more milksolids. Dry matter intake is one of the biggest limitations for milk production in pasture-based systems. When cows are fed a total mixed ration (TMR) or graze high quality spring pasture, more than 60% of the difference in milk production can be explained by the difference in DMI (Kolver and Muller, 1998). In addition, when supplements are added to pasture-based systems, total DMI increases (Roche et al., 2013) and consequently milk production increases. This is known as the marginal response to supplement (MR; kg MS/kg DM supplement) and ultimately results in an increase in milk revenue.

If supplements are added into a system when there is no shortage of pasture, and negative substitution occurs, the actual MR to supplements is less than expected. Reviews by Stockdale (2000) and Bargo et al. (2003) reported an average milk response to supplements of 1 kg milk/kg DM grain or approximately 80 g MS/kg DM grain, when cows are in a marginal feed deficit and there is minimal wastage of supplement and pasture. However, this is a "best practice" or "gold standard" response and both case studies and benchmarking data indicate that the MR on-farm is typically lower than this. As hunger is the main driver of substitution, the MR to supplements decreases as post-grazing residuals increase (Macdonald 1999; Roche et al., 2006; Roche, 2007; Burke et al., 2010). If cows are generously fed on high-quality pasture (post-grazing residuals approximately 1800 kg DM/ha; 9 clicks) the response to 1 kg barley can be as low as 30 g MS/kg DM. In contrast, if cows are in a feed deficit, (post-grazing residuals approximately 1300 kg DM/ha; 6 clicks), the MR may be as high as 150g MS/kg DM barley. In addition, feeding supplements during a feed deficit results in positive substitution as pasture residuals rise and over-grazing is prevented. Using supplements during a feed deficit, also allows the rotation length to be extended without underfeeding the cow, this is the fastest way to grow more grass (feeding the wedge; Lee et al., 2008). Additionally, if feed is short in autumn, supplements can be used to increase lactation length, or to allow for a temporary increase in stocking rate to enable a portion of the farm to undergo pasture renewal.

Increasing peak lactation

Another reason for feeding supplements is to increase MS yield in peak lactation. It is assumed that if peak MS increases, this will have a positive carry-over effect and increase MS for the remainder of lactation. This is sometimes referred to as the '1 in 200 rule', which suggests that if peak production increases by 0.1 kg MS then total production will increases by 20 kg MS. This is based on the fact that when supplements are fed there is both an immediate MR while the supplements are being consumed, and a deferred MR after supplementation is ceased. However, the deferred response is relatively small; cows that were supplemented with 6 kg concentrate for 12 weeks from calving, only continued to produce extra milksolids for another 3 weeks and this extra milk was only equivalent to an additional 12g milksolids (6 g fat and 6 g protein) per kg concentrate DM previously consumed (Roche et al., 2013).

Increasing milk value

In addition to increasing milk production, supplements can increase milk value. In current milk pricing systems, milk protein is worth twice as much as milk fat and, therefore, a higher protein:fat (P:F) ratio can increase the value of a kg of milksolids. The P:F ratio can be manipulated by nutrition due to changes in the products of rumen fermentation. More propionate is produced from the rumen when starch is consumed and more acetate is produced when fibre is eaten (Van Soest, 1994). When propionate is absorbed from the rumen it increases circulating insulin, which simulates protein uptake by the mammary gland (Rius et al., 2010), whereas acetate is the building block for milk fat synthesis. Thus, feeding a starch-based product (e.g. cereal grains) will generally increase milk protein % and decrease milk fat %, whereas feeding pasture, or a fibre-based supplement (e.g. palm kernel, soyhulls) tends to increase milk fat % and reduce milk protein %.

However, it takes a considerable change to the P:F ratio to result in a small change in the milksolids price (Table 2). Research results indicate that cows would need to consume approximately 3.5 kg cracked maize or 4 kg cracked barley/day to increase the P:F ratio by 0.05 (Roche et al., 2006; Higgs et al., 2013). At a $6.00 milksolids price, this increase in P:F ratio would only increase the milk revenue by $0.07 or $0.02 for every kg starch-based concentrate fed. At an $8.00 milksolids price, increasing P:F ratio from 0.75 to 0.80 would only increase milk revenue by $0.09 or approximately $0.03 c/kg starch-based concentrate fed.

Table 2: Effect of change in protein:fat ratio on milksolids value *

P:F ratio	**0.75**	**0.8**	**0.85**	**0.9**
Milksolids (%)	8.50	8.50	8.50	8.50
Protein (%)	3.65	3.78	3.91	4.03
Fat (%)	4.85	4.72	4.59	4.47
Value of 1 kg MS at $6.00	$5.93	$6.00	$6.06	$6.11
Difference per 5 % increase		$0.07	$0.06	$0.05
Value of 1 kg MS at $8.00	$7.91	$8.00	$8.08	$8.15

Difference per 5 % increase		$0.09	$0.08	$0.07

*Based on national average of 3.78% protein, 4.72% fat.

DairyNZ Feed Cost Calculator

The DairyNZ Feed Cost Calculator provides information on the MR to specific supplements based on the post-grazing residual and starch/fibre content of the supplement. It takes into account the milksolids price and relative value of milk protein and fat (i.e. valued component ratio; VCR), supplement wastage, associated costs (including fuel/energy, labour, repairs and maintenance), supplement quality and starch/fibre content. It does not factor in a cost for the impact of over- or under-grazing on pasture growth or quality, nor does it account for the other likely non-feed related costs that increased with supplement use as outlined previously. The decision support resource highlights the impact that post-grazing residuals have on the MR to supplement and the amount that can be spent on feeding supplements. Table 3 outlines an example of a farmer supplying Fonterra with a milksolids price of $6.50, feeding maize grain or barley in-shed, or PKE in trailers in the paddock. If post-grazing residuals are 1200 kg DM/ha the predicted MR to barley is 185 g MS/kg DM, and the Feed Cost Calculator indicates that the farmer can afford to spend $1140/tonne DM on feeding costs to break even. Taking into account the total cost adjustment from Ramsbottom et al., (2014), where the total cost of feeding supplements was approximately 50% greater than the price of the supplement, then the price of barley should be $778 or less before any profit would be made (Table 3).

Table 3. Predicted price that can be paid for supplements using either the DairyNZ Feed Cost Calculator or using an adjustment factor based on total costs from Ramsbottom et al. (2014).

Post-grazing residuals	Feed Type[1]	MR (g MS/kg DM)	DairyNZ Calculator	Adjusted[2]
1200	Maize	205	$1,330	$904
1200	Barley	185	$1,140	$778
1200	PKE	150	$815	$563
1500	Maize	100	$660	$458
1500	Barley	90	$560	$391
1500	PKE	75	$380	$273
1800	Maize	35	$215	$161
1800	Barley	30	$175	$134
1800	PKE	25	$105	$90

[1]The ME of Maize, Barley and PKE are assumed to be 13.5, 12.0 and 11 MJ ME/kg DM respectively.

[2]Adjusted based on Ramsbottom et al., (2014) where total costs were 50% greater than the supplement price.

Milk urea

Using supplements to alter other constituents in milk, such as milk urea (MU) has gained traction recently; however, using MU values to guide feeding decisions is of limited use in pasture-based systems. Milk urea is a crude indicator of the amount of protein in the diet. When there is excess dietary protein, it is converted to ammonia in the rumen. The ammonia is absorbed through the rumen wall into the blood stream and then converted to urea in the liver. Most of the urea is excreted in urine, but some passes into the milk. Due to the crude protein content of high quality pastures, MU values are typically higher in cows grazing pasture compared with cows fed a TMR or high levels of supplement. Contrary to some advice in the dairy industry, high MU levels are not detrimental to milk production, cow health or reproduction and the process of converting ammonia to urea (ureagenesis) is not energetically expensive (Firkins and Reynolds, 2005). The reduction in MU through feeding high-starch supplements is almost exclusively through the reduction of dietary protein and not through increased “capture” of more protein in the rumen.

The only time that high MU levels (approximately > 25 mg/dL) should be considered are in high-input systems, as they may indicate that there is more protein being fed than required. As MU is not a sensitive indicator, the total crude protein content of the diet should be looked at before feeding decisions are made. If the dietary crude protein is in excess of requirements, this may allow expensive protein supplements to be removed from the diet.

In contrast, if MU levels are low in high-input systems or in pasture-based systems during periods of drought, there may be a deficiency of protein in the diet. As with high MU levels, laboratory analysis of feed ingredients and an assessment of the complete diet for protein availability should be undertaken, before any nutritional changes are made. Even if dietary protein levels are lower than recommended, the total cost of feeding the extra protein should be considered and compared with the expected MR before supplements are purchased and fed.

Balancing pasture and crops

With the right decisions, supplements can be used profitably to increase ME intake; however, they are not needed, to “balance” a pasture diet. Pasture is a highly nutritional base feed and is uniquely balanced (Roche et al., 2009). Well-managed temperate pastures are energy dense and meet the cow’s requirements for macro nutrients including high quality protein (18 - 25% of dry matter; DM), non-structural carbohydrate (10 - 20% DM), digestible fibre (30 - 35%

DM), effective fibre (40 - 50% of digestible fibre) and fat (4 - 6%). The futility of replacing good quality pasture with an alternative feedstuff was highlighted when Roche et al., (2010) replaced energy from high-quality, perennial ryegrass-dominant pastures, with an equivalent amount of non-structural carbohydrate (i.e. maize grain). There was a small increase in milk protein yield; however, milk fat yield decreased and there was only a small change to milksolids production and no effect on milk revenue ($/cow/d). The high nutritional quality of pasture was supported when milk production from cows fed a TMR was compared with cows grazing pasture. Less than 10% of the difference in milk production was due to the TMR being a 'more balanced' diet (Kolver and Muller, 1998), and more recent research indicates that even that 10% is overstated. Therefore, with the exception of a drought, when protein may become a limiting factor, energy is the primary limiting component in grazing dairy systems. An energy deficiency can occur if there is insufficient pasture available (pasture cover or allocation) or when cows are unable to consume sufficient pasture due to adverse weather events (snow, prolonged periods of heavy rain and/or wind).

In contrast, if grazing cows are being offered a diet high in crops, as occurs in some winter feeding systems, there is a need to balance the diet to prevent rumen dysfunction and maintain animal health. When feeding crops, in particular crops such as fodder beet that are high in starch, there is a requirement for an additional source of fibre to prevent rumen acidosis. There is information on the necessary supplement requirements for specific crops on the DairyNZ website.

Depending on the region and the individual farm, there are specific minerals that may be deficient in pasture (e.g. copper, cobalt, selenium, iodine and zinc) or in excess (potassium). Addition of those minerals that are deficient in combination with other specific minerals (i.e. magnesium and calcium) may be necessary to prevent metabolic disease. However, these minerals can be added to pasture-based diets (i.e. licks, water (dosatrons), bullets, pasture dusting and injections) without the need to purchase additional supplements.

Feeding supplements to improve body condition score

In addition to trying to increase milk yield and milk value, supplements are often added into pasture-based systems in an attempt to minimise BCS loss during early lactation and/or reach BCS targets at calving. It is virtually impossible to alter the BCS loss that occurs during the first month (Roche et al., 2009; McCarthy et al., 2007) in a healthy cow. The dairy cow is genetically programmed to mobilise body tissue following calving to support the demands of milk production. Feeding supplements during this period will result in greater milk production or greater pasture wastage, but will not prevent BCS loss. After the initial 4-5 week period following calving, feeding supplements can reduce BCS loss; however, the impact of supplementation on BCS in early lactation is small. Feeding 3 kg DM concentrate/d for 100 days from calving increased BCS from 3.9 to 4.2 BCS, therefore the decision to feed supplements should be primarily based on the costs and benefits of increased milk production that were discussed earlier.

The positive impact of reaching BCS targets at calving are well documented and have been set to optimise milk production, reproduction, health and welfare of the cows. When deciding if supplements should be added into the system to alter BCS, there are several factors to consider. Firstly, what amount of BCS change is physiologically achievable? Secondly, what is the financial benefit of gaining the BCS? Analyses of large datasets indicated that increasing BCS at calving from a 4.0 to a 5.0 increased MS production in the subsequent season by 12 kg MS/cow. In addition, cows that were a BCS 4.0 compared with a 3.0 at the planned start of mating had 4-5% greater 6-week in-calf rate. Using a milksolids price of $6.50, these effects are equivalent to $78/cow increased milk revenue and approximately $20/cow from improved reproductive performance. Thus, there is an additional $98/cow income from increasing BCS from 4.0 to 5.0 at calving; assuming not more than 1 BCS unit was lost between calving and mating. This benefit can then be compared with the total cost of feeding supplement to gain BCS.

The amount of pasture and supplement required to gain BCS during the dry period is outlined in the DairyNZ body condition scoring reference guide for NZ dairy farmers. There are differences in the efficiencies (based on a ME basis) with which feeds are used to gain BCS during the dry period. Palm kernel extract (PKE) is the most efficient feed for gaining BCS, while autumn pasture is the least. For example to gain 1 BCS in a 500 kg cow, she needs to eat an extra 125 kg DM PKE, whereas she would need to eat 160 kg DM of either pasture silage or maize silage or 205 kg DM of autumn pasture. Taking into account the benefits of reaching BCS targets at calving and depending on the cost and availability of these feeds, the infrastructure of the farm and time constraints (Kay et al., 2014), decisions can be made as to whether supplements are needed and, if so, which supplements and how much should be used to increase BCS.

Reproduction

Using supplements to reach BCS targets at calving can improve reproductive performance and supplements can be beneficial if they fill an energy deficit during the mating period. When cows were underfed by 40% for two weeks at the planned start of mating, the six-week in-calf rate was reduced from 78% to 71% (Burke et al., 2010). However, if cows have sufficient feed (i.e. target residuals are 1500 - 1600 kg DM/ha) with good pasture utilisation, there are no specific supplements that will improve reproduction. Feeding cows with high-starch supplements prior to mating is a strategy sometimes employed in an attempt to improve reproductive performance. This is based on the premise that concentrates high in non-structural carbohydrates can increase circulating hormones such as IGF-I, which can lead to earlier cycling (Burke et al., 2010). However, research in NZ indicates that 97% of the variation in cycling is related to things other than blood IGF-I levels. If cows have sufficient feed (i.e. target residuals of 1500 - 1600 kg/DM; 7-8 clicks) and concentrates high in non-structural carbohydrates are added to the system, there is unlikely to be an improvement in reproductive rates (Horan et al., 2004). In addition, increased concentrations of IGF-I can negatively affect embryo development after cows have been mated.

Summary - revenue versus costs

Considering the reasons for feeding supplement, the primary contributors to the revenue stream are increased milk production and improved reproduction, with supplement type and its effect on P:F ratio (i.e. milksolids value) being of relatively minor importance.

The effect of supplementation on revenue is dependent on whether or not the cow is underfed and if so, by how much. The increase in MR from supplementation decreases dramatically when post-grazing residuals are greater than 1500 - 1600 kg DM/ha. Furthermore, there is no reproduction

Figure 2. The graph depicts the breakeven price for barley ($/t delivered). The solid line includes the increase in milk revenue from supplementation. The dotted line includes improvements in reproduction. Costs are based on the DairyNZ calculator or adjusted based on Ramsbottom et al., (2014).

advantage to providing cows with supplements in this situation. In comparison, when residuals drop below 1500 - 1600 kg DM/ha, milk production and reproduction responses are likely to be positive and would likely justify the use of supplements from an economic perspective.

Responses to supplements are combined in Figure 2 to provide an approximate breakeven price that can be paid for barley. This accounts for the increase in milk production and reproduction, where appropriate. Figures on the left are derived using the DairyNZ calculator while those on the right include an adjustment for non-feed associated costs that were discussed earlier (Ramsbottom et al., 2014). As would be expected, the breakeven price of supplements increases with milksolids price. However, more important factors are the post-grazing residual and the decision on whether to include those non-feed associated costs.

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