11

Milk responses to supplements

This chapter:

Explains why milk responses to supplements are not consistent and when a supplement becomes profitable to feed.

The main points in this chapter:

- milk responses depend on the substitution of basal forage for supplement
- supplements can affect milk production or cow condition. The total effect on milk production may not be immediate, but during the following lactation
- milk responses to supplementary feeding depend on stage of lactation, the amount, quality and presentation of both the basal forage and the supplement, cow condition, and level of production
- the profitability of supplementary feeding depends on the cost of supplements and the response in milk production, body condition or reproductive performance.

Supplements are fed to improve or maintain milk production, cow condition or reduce intakes of basal forages, when in short supply. Basal forages are the major forages fed by small holder dairy farmers, while supplements include all the additional feeds offered to improve cow performance. Where milking cows can graze for much of the day, the basal forage would be pasture.

The effect of supplementary feeding can be difficult to assess because the results may not appear immediately as milk. In the short term, the response to a particular supplement may be small. But if that supplement is used to ‘save’ on other feeds, for example, until the basal forages become more readily available or until a lower-priced supplement (eg crop residue) can be used, then it may be important and ultimately profitable.

The factors affecting responses to supplementary feeding are numerous (Figure 11.1) and their interactions are complex.

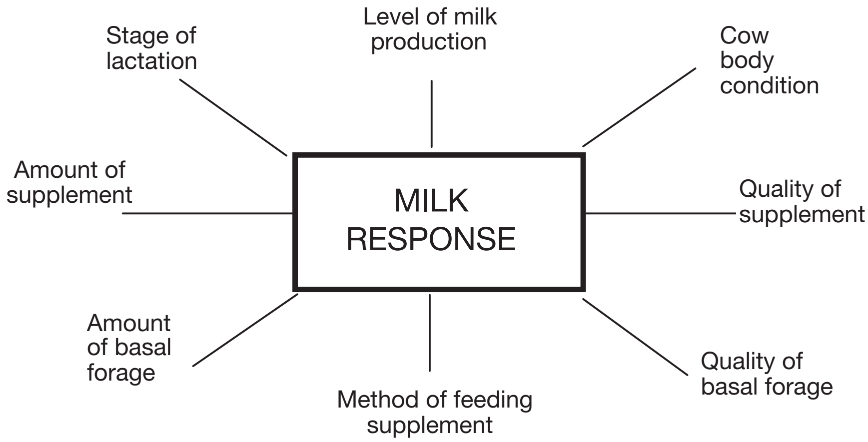

Figure 11.1 Some of the factors influencing milk responses to supplementary feeding.

11.1 Substitution for basal forage

Dairy cows may eat less basal forage when supplements are fed. The term 'substitution' describes the extent to which a supplement replaces the forage which would otherwise have been eaten had the supplement not been offered. The substitution rate is the reduction in forage dry matter intake (DMI) per kg dry matter of the supplement offered. A substitution rate of 0.25 then means that for every kilogram of dry matter of supplement eaten, forage intake will fall by 0.25 kg DM.

The major factor influencing substitution rate is the level of forage intake achieved with no supplements fed. If the supplements are fed when the forage has not been well utilised, it is likely that there will be little response in milk production and much of the forage will be wasted.

Substitution rates vary with:

- amount of forage offered each day – as more forage is offered, substitution is likely to increase
- intake limit of the cow – the closer the cow is to the limit of her feed intake when a supplement is offered, the greater the substitution
- quality of forage – if the forage is the same or poorer quality than the supplement, then the supplement may be eaten first
- type of supplement – substitution is generally greater with roughage (hay, silage) compared to concentrate supplements; this reflects the volume the supplements occupy in the rumen and how quickly they are digested to make room for more feed (ie roughages are bulky and are digested slowly)
- balance of the diet as a result of feeding the supplement – if the supplement corrects a dietary imbalance, less substitution occurs and intakes may increase; however, if an imbalance is made worse, total intake may be reduced.

11.2 How cows respond to supplements

11.2.1 Decreasing marginal responses

As the intake of energy increases, the amount of extra milk produced from each extra unit of energy decreases. In other words, the marginal, or additional, milk response decreases as the level of supplement intake increases.

The major reason for this decreasing marginal milk response is that, with successive increments of feed energy, the cow increasingly partitions nutrients from milk production towards body tissue deposition as milk production approaches the cow's genetic potential. In addition, the stage of lactation has an influence on how much of the supplement's nutrients 'go into the bucket' and how much 'go on the back'. Cows in early lactation tend to lose weight to divert additional nutrients towards milk while those in late lactation tend to repartition nutrients to replace previously lost body reserves (see also Chapter 7).

A second reason for declining marginal responses is that utilisation of one feed type can change with increasing intake of a second feed type, which is known as an 'associative effect'. Efficient digestion of forages, particularly low quality forages, requires an adequate population of fibre-digesting microbes in the rumen. By feeding increasing amounts of high starch concentrates, the proportion of these microbes will decrease as more starch digesting microbes propagate as a result of the higher starch intake. Consequently the digestion of the forage can decrease with increasing intakes of such concentrates. Additional starch excretion may also occur, further reducing feed utilisation. This can be particularly important when feeding high levels of supplements rich in fermentable carbohydrates, as rumen pH can decrease, dramatically reducing fibre digestion.

Supplementary feeding usually results in higher total feed intakes. Increasing intakes are the result of decreased times that consumed feed spends in the rumen where it is exposed to microbial breakdown. If less of that feed is digested and the nutrients are absorbed into the blood stream or pass down the digestive tract, less dietary energy becomes available for use by the animal. The cow partly compensates for this through decreased losses of energy via methane and urine with increasing feed intake. Although this may not be important unless total feed intakes dramatically increase through supplementation, it can contribute to declining marginal milk responses to supplements.

Another factor decreasing milk responses is the often incorrect assumption that all of the supplement is actually consumed. Rarely is there nil wastage, particularly if the supplement is a roughage. Fortunately, stall feeding minimises such wastage, compared to feeding cows while outdoors.

The major difficulty when predicting milk responses to supplementation, even if substitution rates are known, is the lack of information on the relative importance of the above factors. Without such knowledge, dairy advisers can only, probably incorrectly, assume additive effects when feeding a mixture of various feed types, which would tend to overestimate such milk responses particularly when:

- there are marked differences between basal roughages and supplement type
- large amounts (say 5 kg DM/cow per day or more) of supplement are fed.

11.2.2 Immediate and delayed milk responses

Responses to supplementary feeding have both immediate and delayed components. Some of the supplement goes immediately to milk production and some goes to body fat, which contributes to milk production at a later stage when this condition is mobilised.

To manage the feeding of supplements effectively, it is important to know how cows respond to them. The response is variable. It depends on the circumstances in which the supplement is fed.

The response in milk yield is generally due to the extra energy in the supplement. Unless the supplement improves the use of nutrients already in the diet or stimulates intake of the basal forage, farmers will not get any more milk than that produced from the energy the supplement contains.

In practice, forage substitution almost always occurs, resulting in the response being less than that predicted from the amount of energy in the supplement. The response will reduce at least by the equivalent of the energy in the forage no longer eaten. Also, some of the energy in the supplement goes to condition score rather than directly into milk. So the immediate milk response will be smaller again. Most experiments have only measured the immediate response to supplements. Because they are short term (usually only several weeks), they cannot measure the delayed milk response from body condition, hence the total milk response.

Most is known about the immediate response to supplements from studies in temperate countries. Whether these will be similar to responses in tropical countries requires further research. The major differences between temperate and tropical climate zones is the poorer quality of tropical forages and that many supplements are based on by-products, which vary greatly in nutritive value in tropical countries. Another difference may be the poorer quality control in feed mills, hence the greater variation in energy and protein contents of formulated concentrates in tropical countries. Therefore, it is highly likely that milk responses in South-East (SE) Asia will be lower than those in temperate countries.

Guidelines for temperate grazing dairy systems

In early lactation, the average immediate response to feeding concentrates containing 12 MJ/kg DM of metabolisable energy (ME) is 0.6 L of milk per kilogram of supplement dry matter, ranging from 0.2 to more than 1.0 L.

In mid-lactation to late lactation, the average immediate response is 0.5 L of milk per kilogram of supplement dry matter, ranging from 0.3 to more than 0.8 L.

One generalisation sometimes made is that 'you get half the response now and the other half later, when the condition score energy is converted back to milk'.

11.3 Factors affecting milk responses

When trying to quantify the response to a supplement, the main consideration should be whether the supplement meets the cow's need. The major needs are for quantity and quality of feed, both basal forage and supplement.

11.3.1 Quantity of basal forage

Roughages are generally the cheapest feeds available (see Chapter 8) and if sufficient are fed, these can meet the energy requirements for maintenance plus 8 to 10 L/d of milk, depending on forage quality. In peri-urban areas, where by-product supplements may be cheap and purchased roughage expensive, it might be more economical to reduce roughage to a minimum and increase supplements to a maximum. Fluctuations in roughage supplies could then be balanced by increasing supplements, depending on their relative prices.

If cows already have enough to eat, feeding more is unlikely to result in a big increase in milk production. However, hungry cows should give a good response.

There seems to be a good relationship between the amount of basal forage offered and the size of the milk response to supplement. When the quantity of basal forage offered is low, the response to feeding supplement is relatively large. High forage allowances result in little or no response to supplement feeding.

11.3.2 Quality of basal forage

Because of lack of land, most small holders in South-East Asia cannot allow their cows to graze freely as they do in temperate dairy industries. They then 'cut and carry' or 'zero graze' their cows that are tethered in sheds for up to 24 hours each day. The relatively low cost of labour means that the forage is harvested by hand and carried to the cow shed. Harvest intervals are based on compromises between maximising forage yield but also optimising forage quality (see Chapter 8). Unlike temperate grazing systems, small holder dairy farmers do not have to understand the principles of rotational grazing, optimum intervals between grazings and the selection differentials for different nutrients to calculate the nutritive value of forage selected in relation to that on offer.

If the forage quality is as good as the quality of the supplement it replaces, and provided the amount of forage does not limit intake, responses will be small or nil.

If the forage quality is low compared with the supplement quality, responses will be better. This is due to the supplement containing more nutrients than the forage it replaces and because feed of higher quality has a positive effect on total energy intake.

These observations can be expressed simply:

- the more suitable a forage is for milk production, the lower will be the response to a concentrate, whereas
- when forage quality is low and concentrates are able to provide limiting nutrients to the diet, the response will be better.

In a review of published cow performance data on Napier grass-based diets, Muia *et al.* (2000) classified grass quality according to the crude protein requirements for various categories of milking cows based on milk yields. These were for cows at maintenance (5–7% Crude Protein, CP), or producing low (8–10% CP), medium (11–13% CP) and high (14–16% CP) yields of milk. They then predicted feed intakes and cow performance in cows fed various diets differing in Napier grass quality and level of supplements, which were either concentrates or *Leucaena*. These data are presented in Table 11.1, while other relevant data of forage quality and yields of Napier grass have been presented in Table 8.12.

Increasing forage protein content (and other quality measures as shown in Table 8.12) generally led to increasing dry matter intakes per unit live weight. At low levels of supplementation, intakes were stimulated, presumably through higher total dietary protein contents. However, above 30% supplementation, the supplement substituted for forage, up to 50% substitution rate with 60% concentrate in the total diet. *Leucaena* supplementation had little effect on milk yield, presumably because energy was still the limiting factor not supplied by the supplement.

Table 11.1 The effect of forage protein content of Napier grass (*Pennisetum purpureum*) on intake of forage and total dry matter intake (DMI) and on cow performance when supplemented with either concentrates or Leucaena

*Substitution rate is the reduction in Napier grass DM intake per kg supplement DM intake (kg/kg) (Source: Muia et al. 2000)

Forage protein content	5–7%	8–10%	11–13%	14–16%
Concentrate supplemention				
Forage intake (kg DM/d)	10.2	8.2	7.2	4.7
Total DMI (kg/d)	10.2	9.3	10.7	12.3
Total DMI (g/kg$^{0.75}$ per day)	115	113	121	130
Concentrate %	0	12	33	62
Substitution rate*	0	-0.12	0.27	0.54
Milk yield (L/d)	7.6	8.6	9.2	12.4
Live weight change (kg/d)	-0.5	0.0	-0.1	0.1
Leucaena supplemention				
Forage intake (kg DM per day)	6.8	7.1	7.0	-
Total DMI (kg/day)	6.8	8.2	9.3	-
Total DMI (g/kg$^{0.75}$ per day)	83	99	106	-
Leucaena %	0	13	25	-
Substitution rate*	0	-0.22	-0.02	-
Milk yield (L/d)	6.0	6.5	7.1	-
Live weight change (kg/d)	-0.4	0.0	0.1	-

Feeding Napier grass alone supported milk yields of 6.8 L/cow per day, but this was accompanied by live weight losses of 0.4 kg/d. The maximum predicted yield (12.4 kg/cow per day) in Table 11.1 was below expectation (15 L/cow per day), possibly due to shortages of readily fermentable nitrogen for optimum rumen microbial activity (Muia *et al*. 2000).

11.3.3 Quality of supplement

Milk responses vary greatly with supplement quality. In temperate grazing systems, cows generally produce less milk per kilogram of hay Dry Matter than per kilogram concentrate Dry Matter, because of the lower energy and higher fibre content in the hay. This would also be the case in South-East Asia. Therefore, it could be argued that milk responses to feeding very low quality forages, such as rice straw or sugar cane tops, would be even lower than those from formulated concentrates or other energy supplements, such as those described in Chapter 10. However, such feeding decisions are usually made as a result of large shortages in basal forages.

Tree legumes can replace some of the concentrates in supplement feeding strategies. In their review on forage production for small holder farmers in Thailand, Nakamanee *et al*. (1999) reported on African studies in which 3 kg fresh *Calliandra* forage had the same effect on milk production as 1 kg formulated concentrate. Another study recorded a 1 L/d milk response in cows fed 8 kg *Leucaena* to supplement a Napier grass-basal forage.

11.3.4 Allocation of supplement

The overall response in milk yield to concentrate feeding during early lactation depends on the extent to which residual effects on milk yield persist later in lactation. These residual reponses can be expressed later in the same lactation or in the following lactation. Unless the high nutrient demands during early lactation (as discussed in Chapter 7) are met, this can affect cow performance later in lactation.

Using Friesians and Ayrshire milking cows in Kenya, Kaitho *et al*. (2001) demonstrated the production benefits of good feeding management in early lactation. All 18 cows in this trial were fed the same total quantity of concentrates for 300 days (600 kg/cow) but using three different allocations: A, 2 kg/d over 300 days; B, 4 kg/d over the first 150 days; C, 8 kg/d over the first 75 days of lactation. The basal diet was *ad libitum* Rhodes grass (*Chloris gayana*) hay (containing 8% protein and 65% Neutral Detergent Fibre, NDF) while the concentrate was a commercial dairy meal (with 15% protein) fed twice daily. Cows weighed 400 kg at calving and their performance is presented in Table 11.2.

Table 11.2 Measures of cow performance in Friesians and Ayrshires in response to three different allocations of concentrates while fed Rhodes grass hay (*Chloris gayana*) *ad libitum*

Allocation: A, 2 kg/d for 300d; B, 4 kg/d for first 150 d; C, 8 kg/d for first 75 d; *, statistical significance; C is significantly different to A and B. (Source: Kaitho *et al.* 2001)

	A	B	C
Milk yield			
Days 1–75 (kg/d)	12.1	13.2	17.5*
Days 75–150 (kg/d)	8.1	8.4	10.2*
Days 150–300 (kg/d)	6.8	6.3	7.2
Entire lactation (kg)	2544	2562	3155*
Live weight change			
Days 1–75 (kg/d)	–0.38	–0.16	0.17*
Days 75–300 (kg/d)	0.13	0.24	0.21
Reproductive performance			
Calving to conception (days)	106	99	80*
Services per conception	2.2	2.0	1.5

Cows allocated their entire concentrates during their first 75 days of lactation produced more milk in early and mid-lactation and for their entire lactation. They gained weight prior to mating (in contrast to the other two groups that lost weight), hence conceived earlier with fewer services per conception (although this was not statistically significant). Body condition scores, not presented in Table 11.2, improved over the lactation and were always higher in group C than in groups A and B. Milk fat contents did not differ between groups, averaging 3.2%.

Cows have limited gut capacity following calving hence must be fed higher quality diets. The lag of maximum intake behind peak milk yield leads to negative energy balance with cows having to utilise body reserves, to the detriment of their reproductive performance if this energy deficit is too severe. Furthermore, such losses in milk production caused by under feeding cannot be overcome even if the ration is balanced later in lactation. Group C cows, even when fed no concentrates between days 75 and 150 still produced more milk during these 75 days than the concentrate-fed groups A and B.

Therefore, a simple management decision, such as reallocating the same amount of concentrate supplements, can improve milk production and reduce calving intervals. In this study, these benefits were 611 kg milk/cow plus a 26-day shorter calving interval.

11.4 Presentation of the forage and supplements

Milking cows can be offered their diet in many ways:

- grazing the forage and hand fed the concentrates at milking
- grazing the forage, supplemented with additional forages at pasture or on a feedpad and hand fed the concentrates at milking
- zero grazed hence hand fed the entire diet in the shed
- lot fed on total mixed rations, in which forages and concentrates are presented as a blended ration.

The presentation of the diet can influence milk responses in various ways.

11.4.1 Presentation of the forage

Wilting the forage

The optimum total diet dry matter for maximal dry matter intake is 50% to 75%, which can limit the quantity of freshly harvested forage that should be fed, particularly in early lactation.

Large-scale wilting of freshly harvested forages improve feed intakes and milk yields.

With regard to forages, levels of water that exceed 22% (or feeds <78% DM) can restrict forage intake. For example, Minson (1990) reported that for every 1% increase above 82% water content, or for every decrease of 1% unit below 18% DM, forage intake decreased by 0.34 kg DM/d in lactating dairy cows.

Wilting fresh Napier grass for 24 hr increased

Small holder farmers can easily wilt the day's allocation of forage for their stock, prior to feeding.

forage intake and nutritive value in beef cattle and buffaloes (Table 11.3). The Napier grass was harvested every 45 days during the wet season and contained 12% DM, 7.5% CP and 62.2% NDF. The climatic conditions were such that dry matter percentage only increased by 2.6% units following a 24 h wilt. Grant *et al.* (1974) concluded that the loss of moisture was not a factor in increasing digestibility, but it was the result of some chemical or enzymatic changes taking place during the wilting period.

Table 11.3 Effect of wilting fresh Napier grass (*Pennisetum purpureum*) on intake and digestibility by cattle and buffaloes
(Source: Grant *et al.* 1974)

	Fresh	Wilted
Forage DM content (%)	12.0	14.6
DM intake (% LWT)	2.0	2.3
DM digestibility (%)	58.2	64.2
CP digestibility (%)	64.0	70.6
NDF digestibility (%)	54.3	60.8
ME content (MJ/kg DM)	7.9	8.9

McDowell (1994) suggests that wilting forages stimulate appetite through smaller rumen volumes of intracell water and improved rumination of the chewed forage. Furthermore, higher forage dry matter contents will produce a denser mat of predigested forage in the upper rumen, making it easier for this material to be regurgitated during rumination. A faster rate of forage breakdown in the rumen will increase the rate of passage of feed through the cow's digestive tract, hence a greater appetite for more.

Wilting racks can easily be constructed from bamboo and built off the ground to encourage air movement under the freshly harvested forage and so aid water removal from the leaves. Conditioning the thicker parts of the forage, to fracture the epidermal layers, will result in a faster rate of water removal from the plant. Forage can then remain on the wilting racks for up to 24 hr.

It is essential to stack the forage loosely on wilting racks in thin layers, no thicker than 10 cm. If the forage heats up during wilting, its nutritive value will decrease, due to plant sugars being used by bacteria and fungi during heating. In the case of heavy rain, a roof made of tarpaulin or thick plastic should be positioned above the wilting racks, allowing easy removal during sunshine. Rewetting of partially wilted forage requires longer wilting times, which will almost certainly reduce its nutritive value.

To quantify the benefits of wilting, cows in mid lactation were fed chopped Napier grass plus concentrate (6 kg/cow per day) in Indonesia (Moran and Mickan 2004). Wilting the grass for 8 hr increased daily intakes of fresh grass from 40 to 50 kg/cow and increased daily milk yields from 14.2 to 15.7 L/cow. Assuming the concentrate contained 90% DM, the fresh grass 17% DM and the wilted grass 20% DM, the wilting then increased total daily dry matter intakes from 12.2 to 15.4 kg/cow, a daily increase of 3.2 kg/cow. Clearly, wilting is a simple and practical method to improve intakes of freshly harvested forages, leading to increases in feed intakes and hence cow performance.

Chopping the forage

Prior to feeding, all forages should be chopped, either by hand or mechanically. This reduces the opportunity for cows to select from the forage, where they choose the more palatable leaves and reject the coarse stems. Even though the cows will select a diet with higher nutritive value from unchopped material, the wastage from rejected feed can be very high. Farmers may offer less forage, when hand chopping it, to encourage the cows to eat a greater proportion of it. However, in so doing, total forage intakes will be reduced and milk yields will suffer. It is preferable to remove the refusals and offer freshly chopped forage as often as practically possible, certainly two or three times per day.

Table 11.4 Effect of chopping fresh Napier grass (*Pennisetum purpureum*) harvested during the wet or dry season on intake and digestibility by cattle and buffaloes
NS, not significant; *, significant; **, highly significant. (Source: Grant *et al.* 1974)

	Whole	Chopped	Statistical significance
Wet season			
DM intake (% LWT)	1.9	2.0	NS
DM digestibility (%)	54.3	56.0	*
ME content (MJ/kg DM)	7.2	7.5	*
Consumed CP content (%)	7.8	7.6	NS
Consumed NDF content (%)	63.1	63.5	*
Dry season			
DM intake (%)	2.2	2.5	*
DM digestibility (%)	58.5	56.0	*
ME content (MJ/kg DM)	7.9	7.5	*
Consumed CP content (%)	6.6	6.2	**
Consumed NDF content (%)	64.3	65.2	**

Grant *et al.* (1974) compared the intake and utilisation of Napier grass harvested in different seasons and fed whole or chopped. They found that chopping it into 2 to 5 cm pieces increased intake, but only significantly during the dry season (Table 11.4). The Dry Matter digestibility (and hence calculated Metabolisable Energy content) of the grass improved through chopping in the wet season, whereas it was reduced in the dry season. Animals selected grass with higher protein and lower fibre contents when it was offered whole, compared to chopped.

Feeding conserved forages

Cows may consume less of the forage once it is conserved and it will invariably be of poorer nutritive value than when freshly harvested. If cows have never been fed silage, it may take several days before they fully adapt to its taste. Spoiled silage, due to its exposure to air during the ensiling process, is less palatable, and in certain situations, the toxic bacteria can make cows sick or even kill them. Mould in hay and silage will reduce its palatability. As with any forage, fresh or conserved, if it heats up, it will also have reduced palatability.

When designing silage stacks, consideration should be given to reducing the length of the feeding face, when opened, to reduce aerobic deterioration. Similarly, once removed from the silage stack, the longer the delay in feeding out, the more heated it will become. Hot silage has poorer nutritive value that does cool silage (see Chapter 9 for further details about silage feed out management).

11.4.2 Presentation of the concentrates

The 'cut and carry' system provides the opportunity of farmers to reduce grain poisoning or lactic acidosis (see Chapter 13). When cows graze and are only offered concentrates at milking, they may have to consume 50% or more of their total diet within two 10 to 20 min periods. This is called 'slug feeding' because the bacteria in the rumen are suddenly exposed to large amounts of starch in two slugs each day. Rumen pH will invariably fall and fibre digestion may be reduced. At least with zero grazed cows, it is easier to offer smaller amounts of concentrates more frequently.

Preparing concentrate mixtures

It is rare for milking cows to be offered one type of concentrate only, because of their high nutritive demands and the poor nutritive value of tropical forages. Concentrate mixtures usually contain a variety of energy and protein supplements together with minerals, usually macrominerals, and for high yielding cows, maybe even microminerals.

One very simple method of preparing a complex concentrate mix for storage or immediate feeding is to spread each ingredient on top of each other in layers (even the mineral premixes) then collect the mixture into bags or buckets by shovelling it perpendicular to the floor. This method is ideally suited for dry concentrate ingredients, although it could be used each day for offering mixtures containing wet by-products such as cassava or soybean waste.

Molasses blocks are a good supplement, and can be used as carriers of non protein nitrogen or minerals. The blocks are solid, fairly easy to make, transport and store. Molasses intakes should not exceed 20% of the total intake, because at higher levels it will depress digestibility.

Many farmers in South-East Asia mix dry concentrates with water to make a slurry, prior to feeding. There is little benefit in this practice in terms of encouraging stock to consume more or improve its utilisation.

Formulation of concentrate mixture

Many dairy cooperatives throughout South-East Asia have feed mills producing formulated concentrate mixtures. The formulations are usually just for protein and are generally based on typical or 'book' values of nutritive values for the raw ingredients. However, when tested in feed analytical laboratories, such formulations are all too frequently incorrect because of the wide variations in the nutritive value of the raw ingredients.

Problems often exist in distribution to individual farmers, as quantities are small and transportation costs high. Distribution is often implemented by farmer cooperatives, which can also be combined with provision of credit, with deductions from milk payments. Cooperatives can also develop contracts with food processors, such as breweries or vegetable oil extractors, to maintain continuity of supply and control prices of such by-products.

The cost of the formulated concentrate can exceed that of the total of its raw ingredients, meaning that it may be more profitable for farmers to prepare their own mixtures. Ideally this requires frequent analyses of the raw ingredients, which is expensive and may not be accurate because poor resourcing of feed analytical laboratories is all too common. In this case, it would be better to base the formulation on undervalued estimates of energy and protein contents of both the concentrate ingredients and the forages. This can lead to incorporating more of the expensive ingredients in the mix, but such an approach is still likely to be profitable because very few cows are fed to their full potential in South-East Asia.

The profitability of feeding milking cows depends on the marginal cost of additional nutrients fed and the marginal return from extra milk produced, so any extra milk produced as a result of overfeeding some nutrients, above the base level, is often a profitable exercise.

Energy, rather than protein, is the most common limiting nutrient for the milking cow, so basing concentrate formulation on protein may still lead to underfeeding them below their potential. Furthermore, the incidence of induced protein deficiencies in milking cows (see Section 11.5.1) is evidence of inappropriate formulation for protein. Unfortunately it is difficult to obtain accurate estimates of energy from laboratory analysis whereas accurate protein analysis is relatively easy, hence the use of protein as the basis of concentrate formulation.

11.4.3 Total mixed rations

Total mixed rations for milking cows should be based on reliable supplies of high quality forages. One successful example of developing such a system for small holder dairy farmers is in Banueng province, southern Thailand. The local cooperative grows large areas of forage maize for silage, which it then mixes with several by-products such as pineapple pulp, cassava waste, palm kernel cake, white cottonseed and maize grain. These are blended in a stationary mixer wagon, placed in large wool sacks, each holding about 500 kg, then delivered each day to nearby farms for immediate feeding. Dry cows are fed a blended mixture of maize silage, rice straw and concentrates.

Feedlotting cows

Several large-scale dairy feedlots operate in Indonesia and Thailand. These operate with similar management systems to feedlots in developed countries, in that the cows are all owned by a single owner, usually a corporate organisation. A value adding operation, such as an Ultra-High Temperature (UHT) milk processing and packaging plant is often constructed near the feedlot, to maximise profits from the capital intensive enterprise.

The forage supply is often based on small holder cropping farmers in which case considerable negotiations are required to ensure continuous quality control, for example ensuring the forage maize supplied is whole crop (complete with the cob) and not maize stover. As the feedlot depends entirely dependent on small holders, goodwill is essential as contractual obligations may not always be honoured.

Cow colonies

Although these are rarely based on total mixed rations, they allow for more controlled management of small holder farming operations. Sheds of up to 200 cows house stock owned by many farmers (eg each with 5–10 cows) where forages are freshly harvested from near their farms. Frequently the local dairy cooperative owns all the facilities, which may include forage producing areas, silage pits and an effluent recycling system. Well-resourced cooperatives (or local government agencies in countries such as China) even construct a milking parlour for machine milking, rather than hand milking, in the farm complex. Unfortunately, in certain instances, the shed was built and filled with stock prior to the guaranteed regular supply of improved forages. In these cases, rice straw may be the only back up forage, with a consequent marked decline in cow performance.

Each farmer is responsible for the feeding and managing their own cows, but the high concentration of cows can allow for the development of machinery and specialist skills (eg forage choppers, milking machines). Cow colonies generally lead to large-scale calf and heifer rearing sheds, thus allowing for easier monitoring of improved small holder dairy management systems, such as milking hygiene. Furthermore, the shed is generally well constructed in contrast to those on most small holdings.

A cow colony in West Java, Indonesia, where many small holders house their stock in a large shed.

Inside a cow colony in West Java, Indonesia, where many small holders house their stock in a large shed.

Complete diets

There is increasing interest in producing complete diets that can be stored for lengthy periods then easily transported to small holders (eg as feed blocks) in times of forage shortages. Unlike beef cattle and small ruminants, milking cows require at least 40% of their diet as forage, and offered in large particle sizes (not finely ground as required to produce feed blocks), meaning that it is not easy to produce an easy-to-handle complete diet. It would be possible to produce a complete diet using alternative roughage sources, such as ground nut shells.

Furthermore, using fresh forages as the forage source (as against straw) requires a major cost in drying such material. Entrepreneurs in Australia have developed a forage-drying shed based on black roof and walls and pumped hot air into a grass drying chamber. Excess forages are usually available only during the wet season making them difficult to field dry to at least 85% DM as the lack of solar radiation would necessitate the use of auxiliary power based on fossil fuels. Such complete diets would be prohibitively expensive, particularly for cash-poor small holder dairy farmers.

11.5 Specific examples of incorrect supplementary feeding practices

11.5.1 Induced protein deficiencies

In many tropical countries, one often finds very fat cows only producing a little milk. This is a classic symptom of induced protein deficiency, brought about by feeding low protein supplements to cows already eating low protein basal forages. The easiest way to diagnose this problem is to monitor milk responses to the supplement, then increase the protein content of the supplement, and note any changes in milk response. If the second milk response is greater than the energy contained in the additional protein fed, the initial diet (of basal forage plus supplement) is likely to have induced a protein deficiency.

11.5.2 Feeding inappropriate supplements

In most tropical feeding systems, the major limiting factor is energy. Unfortunately, there is increasing publicity from commercial enterprises that milk responses can be improved by feeding 'Brand X' supplement containing additional vitamins and minerals or 'Brand Y' supplement containing probiotics or rumen modifiers (these can improve rumen digestion, hence feed utilisation). These particular supplements have been developed for intensive feeding systems, such as dairy feedlotting in temperate countries.

They are often called 'magic bullets' because their manufacturers claim excellent milk responses (and improved cow performance) in many different feeding systems. They may be appropriate for intensive dairy systems where cows can consume sufficient dietary energy and protein, such that other nutrients are limiting milk responses. Furthermore, in these feeding systems, cows may be producing 30 L/d or more, not the 10 to 15 L/d typical of small holder dairy systems.

When confronted with such publicity, farmers and advisers should query their relevance unless the information includes results from studies specific to the small holder dairy systems for which they are being promoted. Furthermore, the independence of the researchers undertaking any relevant studies needs to be assessed. In many cases the farmers' money would be better spent on increasing supplies of dietary energy (or protein if feed supplies are adequate) to the current system.

Unless sufficient dietary energy is offered, milk responses to other forms of nutrient supplements are not likely to be large, or profitable.

11.5.3 Feeding milking cow supplements to young stock

Throughout South-East Asia, most formulated supplements for milking cows are formulated to 16% CP, even though on closer investigation (J Moran unpublished 2003), they are frequently below this content. For convenience, many small holder dairy farmers also feed these concentrates to their young stock. Such formulations are far from ideal because, for optimal growth and health, milk-fed calves and weaned heifers require 18% CP in their total diet (basal forage plus supplements). Depending on the quality of the basal roughage fed post-weaning, 18% may be insufficient for the concentrates.

Very rarely can small holder farmers purchase higher protein formulated concentrates and all too often they are not even aware of the benefits for their young stock in supplementing available milking concentrates with additional protein supplements.

High protein concentrates may be available, but at great expense, as they have been formulated for pig and poultry and incorporate high-quality protein ingredients. It would be ideal if a few large-scale feed mills, either owned by dairy cooperatives or agribusiness, could formulate calf and heifer mixes with higher protein contents, utilising better quality energy sources and additional minerals and vitamins for optimal growth of young stock. Compared to the higher demand of concentrates specially formulated for milking cows, the formulation of smaller batches of calf and heifer mixes would not be cost effective for small dairy cooperatives.

11.5.4 Excessive use of supplements

Overuse of concentrate supplements can reduce forage utilisation through metabolic disorders, such as lactic acidosis (see Chapter 13). As already mentioned in this chapter, associative effects reduce forage utilisation at high concentrate feeding levels.

If the cows are already well fed, overuse of concentrates can reduce milk responses because cows may already be producing relatively well. For example, increasing milk yields by 2 L/d, from 20 to 22 L/d requires more additional nutrients per litre of extra milk than increasing milk yields by 2 L/d, from 10 to 12 L/d.

Farmers must be the ultimate judges of whether milk responses to a particular supplement are sufficiently large (and profitable), based on observations of their herds' performance when fed certain basal forages. Farmers can then make their own decisions as to the most economic level of feeding of that supplement in their own system. Most farmers have a good idea of how their cows are performing and, with a little guidance, can learn to monitor the most appropriate production indices.

A simple test to determine the size of the response is to put 1 or 2 kg of supplement into the diet, or take 1 or 2 kg out, then monitor its effect on cow performance, such milk yield and forage intake.

11.6 Milk yield and total diet quality

11.6.1 Energy content of the diet

In temperate dairy systems, cows can produce 20 to 25 L/d of milk on grazed pastures alone. However, with the lower quality of tropical forages, it is essential to feed supplements to produce more than 8 to 10 L milk/d. Muia *et al.* (2000) only recorded cows fed 100% Napier grass to produce 6.8 L/d of milk (Table 11.1). McDowell (1994) estimated the total diet quality for various levels of Friesian cow performance (Table 11.5). These values underestimate the required metabolisable energy contents by up to 0.5 MJ/kg DM (J Moran, pers. obs.).

Table 11.5 Estimated required diet quality for expectations in performance
Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: McDowell, 1994)

Expected cow performance	Level of milk production (L/d)	Estimated ME content (MJ/kg DM)	Estimated TDN content (%)
Maximum genetic performance	>35	10.0	>70
Intermediate performance	20–24	8.2	60
Medium performance	12–16	7.3	55
Low performance	3–6	6.5	50
Maintenance	–	5.6	45
Live weight loss	–	<4.8	<40

The higher the quality of the forage, the less concentrates necessary to achieve the desired milk yield. Devendra (1975) estimated the amount of concentrates required for target milk yields in 400 kg milking cows (non-pregnant with zero weight change) when fed *ad libitum* forage of varying qualities (Table 11.6). He assumed the concentrate to be home mixed and to contain 12.2 MJ of ME kg DM and 24% protein.

Table 11.6 Required concentrate intakes (kg DM/day) for cows fed forages of varying quality to achieve target milk yields
(Source: Devendra 1975)

Milk yield(L/d)	Forage quality Digestibility (or ME in MJ/kg DM)			
	55% (7.3)	60% (8.2)	65% (9.0)	70% (9.9)
6	3.2	0.7	–	–
10	4.9	2.5	0.8	–
14	6.6	4.8	1.1	0.3
18	8.2	6.0	3.0	0.7
22	9.8	7.7	5.4	1.7

In Indonesia, Hendrawan (2003) estimated the intakes of both concentrate and fresh grass required for target milk yields in cows of varying live weight and assumed zero live weight change (Table 11.7). Details of the grass were not provided whereas the concentrate was assumed to contain 87% DM, 18.2% protein and 77% TDN (or 11.1 MJ of ME/kg DM).

Table 11.7 Required daily intakes of concentrate (C) and freshly harvested grass (G) (kg/d) for cows of varying live weight to achieve target milk yields
(Source: Hendrawan 2003)

Milk yield (L/d)		Live weight (kg)				
		300	**350**	**400**	**450**	**500**
8	C	5.3	5.9	6.4	6.5	6.8
	G	30.0	32.0	34.0	36.0	38.0
12	C	6.5	7.1	7.4	7.7	8.0
	G	36.0	39.0	41.0	43.0	45.0
16	C	7.7	8.3	8.7	8.3	8.7
	G	43.0	46.0	48.0	46.0	48.0
22	C	9.6	10.1	10.4	10.7	11.0
	G	53.0	56.0	58.0	59.0	62.0

One example of a practical feeding system developed in Indonesia by Alim *et al.* (2001), for well-managed small holder farmers is presented in Table 11.8. This is for 500 kg cows, each producing 5000 L in their 3rd lactation while fed a mixture of forages (maize stover, Napier grass, field grass) and various concentrates (formulated mix with additional coconut meal and maize grain during early lactation). The recommended formulated concentrate should have 16 to 18% CP and 70% TDN (or 9.9 MJ of ME/kg DM). The quantities of roughage fed in Table 11.6 are considerably lower than those required for similar milk yields in Table 11.5, but this might be partly because of expected live weight changes in the year round system.

Table 11.8 Recommended feeding system for Indonesian small holder farmer utilising roughages (R) and concentrates (C). Units are L/d for milk and kg fresh/d for feeds

Roughages (R) are maize stover (MS), Napier grass (NG) and field grass (FG). Concentrates (C) are formulated concentrate (FC), cottonseed meal (CM) and maize grain (MG). (Source: Alim *et al*, 2001)

Month of Lactation	Milk Yield (l/d)	MS	NG	FG	FC	CM	MG	R	C
Pre Calving	–	15	45	–	3	–	–	60	3
1	23	22	15	–	10	1	1	37	12
2	23	30	–	–	15	1	1	30	17
3	21	30	–	–	12	–	1	30	13
4	19	10	20	–	11	–	–	30	11
5	17	10	20	–	10	–	–	30	10
6	15	10	20	–	9	–	–	30	9
7	14	10	25	–	8	–	–	35	8
8	12	–	15	25	7	–	–	40	7
9	11	–	15	25	6	–	–	40	6
10	10	–	15	25	5	–	–	40	5
Total	5000	4020	6255	2250	2930	60	90	–	–

11.6.2 Excess dietary protein

Milking cows require diets containing 12 to 18% CP, depending on their stage of lactation and milk yield (Target 10 1999). Milk responses to supplements can be reduced if dietary protein contents are outside these optimum levels. Induced protein deficiencies have been briefly mentioned in Section 11.5.1 but in rare instances there can also be a problem with induced protein excesses. It would not be common for small holder farmers to offer diets containing 25% or more of crude protein, with much of this protein as rumen degradable. This could occur for example, when supplementing immature grasses or legumes with concentrates rich in rumen degradable protein.

High levels of Rumen Degradable Protein lead to excess rumen ammonia, which must be detoxified in the liver in order to be excreted as urea in the urine. The metabolic costs associated with this process require energy, which would otherwise be used to produce milk. This 'urea cost' may result in 1 to 2 L/d less milk (Cohen 2001). Feeding cereal grains or supplements high in readily fermentable carbohydrates will allow rumen microbes to capture this Rumen Degradable Protein and synthesise microbial protein, for ultimate use by the cow to produce milk.

Diagnostic tests are available in developed countries to measure the urea content of milk, as an indicator of the imbalance of rumen degradable protein in the diet.

11.7 When is supplementary feeding profitable?

The economic effect of supplements should be assessed in relation to the overall farm feeding system. Nevertheless, it is the short-term milk response that impacts on immediate cash flow. Chapter 17 discusses a simple measure of profit, 'milk income less feed costs'.

It is not easy to assess whether supplements are providing extra profit for small holder dairy farmers without accurate information on immediate and delayed milk responses from particular feeding scenarios. The following are examples of such calculations and assume that milk responses are only half of those derived from temperate grazing studies.

11.7.1 Survival feeding

The profitability of supplements is easiest to determine when feed intake is well below cow requirements. It will not only be a matter of profitability, but of survival. The animal needs to be fed to survive.

11.7.2 Moderately well-fed cows

The next level is when cows are moderately well fed. A typical total milk response for concentrate supplements in small holder dairy systems in Thailand may be about 0.25 L now and perhaps 0.25 L later for each kilogram dry matter of supplement. A simple assessment of feed costs and profit in Thai baht or Bt would suggest break-even is when the cost of the supplement is equal to the value of the total milk response.

12 Bt/L (milk price)	× 0.25 L/kg DM of supplements fed (immediate response)	= 3 Bt
	× 0.25 L/kg DM of supplements fed (delayed response)	= 3 Bt
	Total benefit	= 6 Bt

In this case, it is profitable to feed the concentrate supplement if it costs less than 6.0 Bt/kg DM.

11.7.3 Well-fed cows

A third situation is when cows are well fed with basal forages but concentrate supplements are fed to increase milk yield. The total response from each kilogram of dry matter of supplement fed will be closer to 0.12 L now and perhaps 0.12 L in the next lactation coming from improved condition. The break-even point to make a profit from this can be estimated as before.

12 Bt/L (milk price)	× 0.12 L/kg DM of supplements fed (immediate response)	= 1.4 Bt
	× 0.12 L/kg DM of supplements fed (delayed response)	= 1.4 Bt
	Total benefit	= 2.8 Bt

The supplement would need to cost less than 2.8 Bt/kg DM for supplementary feeding to be profitable.

11.7.4 Other reasons for feeding supplements

Supplements are fed for their beneficial effects on more than just milk production.
For example:

- Without supplementary feeding, cows may lose too much body condition, which could affect their ability to get 'in calf'.

- Basal forages may be in short supply and the only other feedstuffs available are very low quality forage supplements such as rice straw or sugar cane tops. Even though milk responses are very low, cow survival and subsequent fertility may be endangered without including such low quality forages in the feeding system.
- Feeding concentrate supplements may enable farmers to increase their herd size. This may be justifiable so long as the extra milking cows can be relatively well fed (see Chapter 17).