TechNote 18

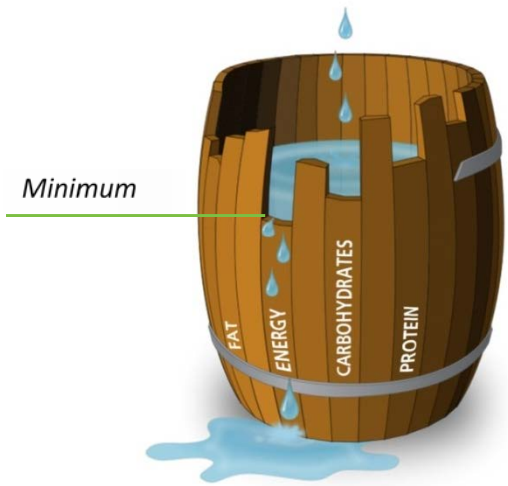
Allocate required nutrients

IN THIS TECHNOTE

In pasture-based systems, energy is generally the primary limiting nutrient and thus, if energy is sufficient, there is no production benefit of trying to balance a good quality pasture diet in spring. In systems where supplements make up a high proportion of the diet, varying nutrients such as protein, fibre, carbohydrate and fat may need to be considered, taking into account cow requirements and economics of purchasing specific supplements. With minerals, in addition to magnesium and calcium, grazing dairy cows may also require supplementary copper, cobalt, zinc, iodine, and selenium depending on the location and herd.

18.1 Determine the limiting nutrient

To determine if the cow requires more of a particular nutrient in the diet, the first step is to determine which nutrient(s) are limiting performance. A good analogy is a barrel with staves of unequal length. The ability of the barrel to hold water is limited by the shortest stave. It does not matter how much longer the other staves are made, the barrel will still not hold more water.



This analogy can be applied to a cow's milk production in early lactation. The amount of milk produced is limited by the nutrient that is in shortest supply compared with requirement. Therefore, increasing the supply of non-limiting nutrients will not increase milk production.

For example: if energy is the limiting factor for milk production, increasing the protein content of the diet will not increase milk production, unless energy is also increased.

If cows are eating an appropriate amount of good quality pasture, the supply of protein(cp), soluble sugars and starch (SSS), fibre (NDF) and fat will be more than adequate to meet requirements (Table 1).

In support of this, production from cows being fed a balanced total mixed ration (TMR) was compared with cows grazing pasture during early lactation. A biological model (CNCPS) was used to determine that approximately 90% of the difference in milk production (44.1 kg vs 29.6 kg milk/cow/day) was due to energy available for milk production (e.g. increased feed availability, greater DM feeds and reduced activity in a TMR system) and only 10% of the difference was due to nutrient composition of the diet.

For more details see TechNote16: Determine energy requirements.

Table 1. *Nutrients in spring pasture.*

ME	CP	NDF	SSS	Fat
MJ/kg DM	% DM			
12.0 – 13.0	24 - 28	38 - 45	7-25	4-6

18.2 Feed protein to meet requirements

Unless milksolids production is greater than 2.4 kg MS/d, recommended dietary protein levels during early lactation are 18% crude protein, of which 65% is degradable in the rumen, while 35% is undegradable dietary protein (Table 2). Dietary protein required can be calculated using the daily feed intake and the crude protein content of each feed (Table 3).

For more details see TechNote 6: Protein metabolism.

Table 2. *Protein recommendations for an early lactation dairy cow.*

Milksolids	Protein (% DM)		
Kg MS/cow/day	Total protein	Rumen degradable protein	Undegradable dietary protein
< 2.4	18	65	35
> 2.4	24	65	35

Table 3. *Example of dietary protein calculation.*

	FEED EATEN		CRUDE PROTEIN	
Feed	kg DM	% of diet	% of feed	% of diet
Spring pasture	10	62.5% (*10 ÷ 16*)	27%	17% (*27 x 0.625*)
Maize silage	4	25% (*4 ÷ 16*)	8%	2% (*8 x 0.25*)
PKE	2	12.5% (*2 ÷ 16*)	18%	2% (*18 x 0.125*)
TOTAL	**16 kg DM**			**21% CP**

18.2.1 Supplementary protein is not required with good quality pasture.

HIGH PASTURE

Spring ryegrass pasture is generally high in good quality protein. Therefore if cows are grazing an appropriate amount of good quality pasture they will have an adequate supply of protein.

If cows have an adequate amount of good quality pasture there is no benefit of supplementing with feeds high in rumen degradable protein.

This is because a high proportion of the crude protein in pasture is rumen degradable protein (70 – 90%) and a large proportion of this is degraded in the rumen providing a source for microbial protein. There is a limit to the amount of microbial protein that can be produced in the rumen, and although the fast rumen passage rate with spring pasture means a portion of the degradable protein passes through the rumen undegraded, there is still more protein digested in the rumen than can be utilised by the rumen microorganisms. Therefore, supplementing pasture-fed cows with feeds high in rumen degradable protein (e.g. silage) or feeds high in non-protein nitrogen (e.g. urea) during spring will be of no benefit.

For more details see TechNote 6: Protein metabolism.

If cows have an adequate amount of good quality pasture, there is no benefit of supplementing with by-pass protein.

Although spring pasture is highly degradable, the fast rumen passage rate during spring time means some of the degradable protein flows through to the small intestine undegraded and contributes to the metabolisable protein pool.

Combined with the high crude protein content of spring pasture (20 – 30% crude protein) there is more than enough dietary protein passing through the rumen and contributing to metabolisable protein.

Q: Does protein increase appetite?

A: As a rule of thumb, no. Adding more protein to the diet than what the cow requires does not increase intake.

For more details see TechNote 6: Protein metabolism.

If cows have an adequate amount of good quality pasture, changing the non-structural carbohydrate content of the diet does not capture more protein in the rumen.

Attempting to "capture" more microbial protein without providing additional energy will not increase milksolids production. Because of its high digestibility, good quality pasture provides the rumen microbes with the same amount of energy as non-structural carbohydrates and thus allows the same amount of microbial protein to be formed.

Therefore, a cow eating the same amount of energy from good quality pasture, compared with pasture plus a supplement high in non-structural carbohydrates (e.g. barley), or pasture plus a supplement low in non-structural carbohydrates (e.g. broll), will produce a similar amount of microbial protein (Table 4).

This means these cows will all have the same amount of protein reaching the small intestine, and, as a result of the similar energy intake and metabolisable protein production, will produce the same amount of milksolids (Table 4).

For more details see TechNote 6: Protein metabolism.

Table 4. Predicted production of microbial protein from pasture, and pasture plus high (barley) and low (broll) non-structural carbohydrate supplements.

Diet	ME intake	% DM			kg/cow/day	
kg DM	(MJ ME/day)	Crude protein	Soluble sugars and starch		Microbial protein	Milksolids
16 kg pasture	185	23	20	2.0	1.1	2.0
12 kg pasture + 4 kg barley	185	20	30	2.0	1.1	2.0
12 kg pasture + 5 kg broll	190	22	24	2.1	1.1	2.1

There is no performance response when synchronising the release of nitrogen from pasture with the release of energy from a rapidly fermentable carbohydrate.

When a high starch feed is fed (e.g. grain) in synchrony with a high protein feed (e.g. pasture) there is an initial decrease in rumen ammonia concentration, suggesting increased capture of nitrogen as microbial protein. However, this effect is transient and there is no increase in the total amount of nitrogen captured, or milk produced, when grain and pasture are fed together compared with feeding the grain in the shed and pasture separately.

Milk urea

Milk urea is a by-product of the breakdown of dietary protein in the rumen and is associated with the protein content of the diet. However, it's use in pasture-based systems is minimal.

Urea is formed when excess ammonia in the rumen (produed from rumen degradable protein and non-protein nitrogen) is transported to the liver and converted to urea. Urea is then either recycled to the rumen, transported to the kidneys and excreted via urine, or transported to the mammary gland and incorporated into milk.

It is not recommended to make dietary changes based on milk urea values alone as there are many animal and feed factors that alter the production of milk urea. In addition a wide range of milk urea values are provided, dependent on laboratory storage and analyses methods, Laboratory analyses of feed ingredients, and/or an assessment of the complete diet for protein (Table 3), protein type and amino acid availability, should be undertaken before any nutritional/dietary changes are made.

For more details see TechNote 6: Protein metabolism.

18.2.2 If a high proportion of supplements are fed, ensure proteins requirements are met economically

If cows are being fed a high proportion of supplements or a mixed ration (partial or total mixed ration), different nitrogen containing feeds can be used to meet the dairy cow's protein requirements. These will vary depending on the total protein content of the diet and the proportion of protein that is degradable compared with undegradable.

Models such as 'Rumen8' or 'CNCPS' can be used to determine if the cow's dietary protein requirements are being met. The DairyNZ FeedChecker can also determine if protein is limiting production.

Supplements that contain high levels of by-pass or undegradable dietary protein (e.g. soyabean meal, or fishmeal) are generally expensive, so even if dietary protein is limiting production, consideration needs to be given to the milk production response and the cost of feeding the supplement, before it is added to the diet.

Supplements that contain non-protein nitrogen (e.g. urea) are relatively cheap. Urea is 46% N equivalent to 288% crude protein, but this is non-protein nitrogen so can only contribute to the microbial protein pool. If a large proportion of supplements are being fed and rumen degradable protein is less than 65% of dietary protein, then urea can provide a source for microbial protein production.

However, feeding urea is not recommended unless it is carefully measured and monitored. A source of rapidly degradable carbohydrate is required in the diet, so that the rumen microorganisms have enough available energy to make use of the rapid release of nitrogen (ammonia) from the urea. If the ammonia cannot be utilised quickly by the microorganisms, there is a sharp increase in ammonia in the rumen, leading to toxicity and in severe cases, even death.

Recommended levels of feeding urea as part of a ration are no more than 150 g/cow per day, ensuring that it is introduced slowly into the diet, mixed in well with other feeds and that there is a source of rapidly degradable carbohydrate available.

For more details see TechNote 6: Protein metabolism.

18.3 Feed carbohydrates to meet requirements

The main energy source for the early lactating dairy cow comes from ruminal fermentation of carbohydrates. These can be divided into soluble sugars and starches (non-structural carbohydrates) or structural carbohydrates (cellulose and hemicellulose).

For more details on protein types and metabolism see TechNotes 3: Feed components, and 5: Carbohydrate metabolism.

The type of carbohydrate in the diet (sugar, starch or structural carbohydrate) affects rumen function and the proportion of each VFA produced, which in turn affects cow performance and milk composition (Figure 1). Milk production is maximised when non-structural carbohydrates (sugars and starches) make up 35% of the diet. In contrast, rumen function and animal performance is compromised when these carbohydrates exceed 38% of the diet, or if starch alone is in excess of 30% of the diet (Table 5).

Table 5. *Dietary soluble sugars and starch (SSS) recommendations.*

	Maximum recommendation (% diet DM)	
Diet	**SSS**	**Starch**
Pasture/pasture + supplement/TMR	38	30

18.3.1 Carbohydrates in good quality pasture are highly digestible

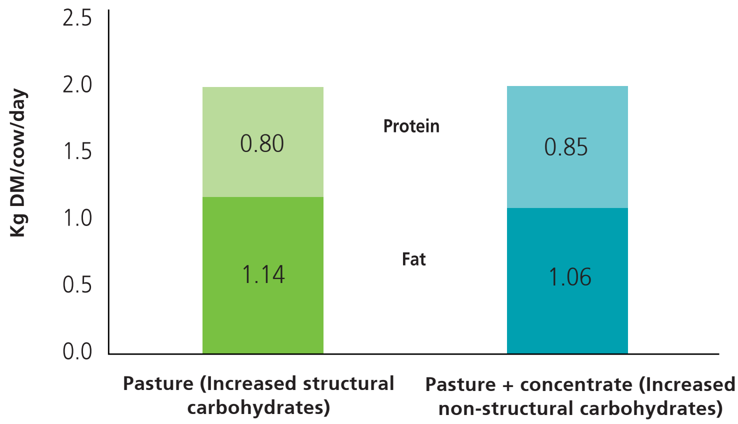
HIGH PASTURE

In a pasture-based system, trying to increase the amount of soluble sugars and starch (non-structural carbohydrates) in the diet is generally not cost effective. Although pasture does not contain 35% soluble sugar and starches, (which is deemed optimal for maximising milk production with a TMR), the structural carbohydrates in good quality leafy spring pasture are highly digestible (70 – 85%) and degraded relatively quickly in the rumen. Thus they supply similar energy to the non-structural carbohydrates.

Therefore, altering the carbohydrate source by adding supplements high in non-structural carbohydrates to grazing cows will change the milk composition, but will not increase energy generated from microbial fermentation or total milksolids production, unless the total energy of the diet is increased (Figure 1).

> Unless total energy of the diet is increased, feeding a high starch supplement to a grazing dairy cow will not improve performance.

Figure 1. *Milksolids production from two herds fed either pasture, or pasture + concentrate at the same energy level (Roche et al., 2010).*



As plants mature, their cell walls become lignified. As the amount of lignin increases, the digestibility of the plant and the availability and utilisation of structural carbohydrates reduces. This slows the production of VFAs in the rumen and reduces the energy gained from the feed. Therefore, maintaining high quality pasture is important to supply high quality carbohydrates to the cow.

> Maintaining high quality pastures maximises the amount of highly digestible carbohydrates available for the cow.

18.3.2 Ensure carbohydrate choice is cost effective when feeding high levels of supplements

HIGH SUPPLEMENT

In a diet that contains a large proportion of supplementary feeds, the choice of feeds can be manipulated to optimise different sources of carbohydrates. Increasing the proportion of soluble sugars and starches (non-structural carbohydrates) in the diet will increase protein production. This can be compared with an increase in the proportion of structural carbohydrates in the diet which results in greater fat production (Figure 2). However, feeds containing a high percentage of non-structural carbohydrates tend to be more expensive, so care is required to ensure production is profitable. Even though milk protein is more valuable than milk fat, the cost/benefit of feeding different carbohydrate sources to alter milk composition needs to be determined. Models such as 'Rumen8' and tools such as the 'DNZ – DietChecker or Supplement Price Calculator' can be used to determine dietary requirements, and the cost/benefit of supplementing with feeds containing different carbohydrate sources.

For more details see TechNotes 3: What's in a Feed, and 5: Carbohydrate metabolism.

Figure 2. Impact of different carbohydrates on milk composition.

18.4 Ensure dietary fibre meets requirements

Fibre includes the structural carbohydrates (cellulose and hemicellulose) plus lignin. A lactating dairy cow has a minimum requirement for fibre to ensure efficient rumen function (Table 6).

Table 6. Dietary fibre requirements.

	Minimum reccomendations (% diet DM)		
Diet	**NDF**	**eNDF**	**ADF**
Pasture	35	17	19
Pasture + supplement/TMR	27	20	19

For pasture-based diets, neutral detergent fibre (NDF) should not drop below 35% DM, with effective fibre (eNDF; the fibre that is most effective at stimulating rumination) making up 17% of the diet.

For diets with a high proportion of supplements, or a TMR, minimum NDF is 27% and eNDF 20%.

These minimum levels are recommended to prevent a rumen dysfunction and reduction in digestion. It is sometimes suggested that if the NDF content of the diet is much higher than this, dry matter intake will be limited. When cows are grazing good quality pastures, NDF is highly digestible and rapidly degraded and thus only accounts for a very small variation in DMI. It is not until pasture quality decreases and/or dietary NDF levels are greater than approximately 50%, that NDF plays a bigger role in intake regulation.

For more details see TechNotes 17: Allocate spring pasture correctly and 23: Allocate required nutrients.

18.4.1 Ensure diet contains adequate effective fibre (eNDF)

Although there are difficulties in estimating the effective fibre (eNDF) content of pasture, there does not appear to be any nutritional benefit from adding additional eNDF (e.g. straw, hay) to cows grazing good quality pasture.

Research data indicated no benefit to milk production or rumen function when straw was added to pasture-based diets in spring. In fact, milk production was compromised as high quality pasture (12 MJ ME/kgDM) was replaced with low quality straw (6 MJ ME/kg DM), reducing the total energy of the diet and potentially limiting intake due to a slower rumen passage rate.

For more details on see TechNote 8: Fibre metabolism.

18.4.2 Grazing cows can tolerate lower rumen pH levels

Rumen pH is a measurement that is used to indicate rumen function.

In cows fed a pasture-based diet, the optimal range of rumen pH is between 5.8 and 6.4, with only a small decrease in fibre digestibility (0.7 MJ ME/kg DM) as pH drops from 6.4 to 5.8. If rumen pH decreases below 5.8, there is a greater decrease in digestibility, equivalent to approximately 1.5 MJ ME/kg DM. Therefore, the rumen acidity or pH threshold for pasture-fed cows, below which fibre digestion is impaired, is pH 5.6.

For cows fed a TMR, a rumen pH above 6.2 is recommended as being optimal for rumen function and, in particular, fibre digestion. Rumen pH below this threshold results in impaired rumen function, reduced fibre digestion and reduced DMI and performance.

The different rumen pH thresholds are due to the different carbohydrate contents, rumen microbial populations and subsequent fermentation products from the different diets.

- When cows are fed a diet containing a large proportion of high starch concentrates, there is preferential microbial degradation of starch instead of fibre, and as the rumen pH decreases, there is greater production of lactic acid. This can result in rumen acidosis, laminitis and if severe can cause metabolic acidosis and death.
- In contrast, in a pasture-based diet, even though production of lactic acid increases as rumen pH decreases, lactic acid only accounts for a very small proportion (1%) of total acids produced in the rumen, with the predominant acid being acetic acid. Thus even at rumen pH levels below pH 6.0, the amount of lactic acid produced is well below levels associated with ruminal or subacute ruminal acidosis.

For more details see TechNotes 5: Carbohydrate metabolism, and 8: Fibre metabolism.

18.5 Ensure dietary fat does not exceed recommendations

The recommendations for dietary fat is not to exceed 6-8% of the total diet. The response to supplementary fat is influenced by:

- basal diet,
- stage of lactation,
- fatty acid composition of supplement (saturated vs unsaturated and protected vs non-protected),
- amount of fat fed.

Fat supplements are sometimes added to the diet to increase energy intake. However, the milk yield response to supplemenary fat is curvilinear; the response diminishes as supplementary fat in the diet increases. Higher levels of fats, particularly unsaturated fats, will actually reduce rumen fermentation, fibre digestion, DMI, and decrease cow performance.

A small amount of protected fat can be added to the diet without detrimental effects on rumen function and fibre digestion. However, supplementary fats (particularly protected fats) are generally expensive, and in most scenarios the cost of the supplement outweigh the benefit of feeding it.

For more details see TechNote 7: Lipid metabolism.

18.6 Ensure minerals meet requirements

18.6.1 Feed additional minerals if required during spring

In addition to the main minerals that may be required in early lactation (e.g. calcium and magnesium) there are five trace elements likely to be deficient in grazing dairy cows and recommended for supplementation from 2-3 weeks pre-calving until 4 months post-calving.

These are copper, cobalt, selenium, iodine and zinc. Consult a veterinarian to determine mineral requirements in your herd.

Copper	Deficiency of copper is common in grazing cows as the content of copper in pasture is low and copper absorption is also low. If cows are not receiving more than 100 mg copper/day from their diet, then they should be supplemented with 200-300 mg copper. This equates to approximately 1-2 g copper sulphate per cow/day in water or a mineral mix, 20 g bullet of copper oxide or the recommended level of injectable copper. Caution is necessary with copper supplementation as toxicity can also occur. If copper is being supplied via high copper feeds such as PKE, indirectly via fertiliser applications or natural high concentrations in the water, then this needs to be taken into account when deciding a supplementation strategy.
Cobalt	The primary reason for supplementing cows with cobalt is to ensure adquate vitamin B12 is produced by the rumen microorganisms; however, other benefits include enhancing digestion of fibrous feeds. The current recommendation is to supplement cows with 8 to 10 mg of cobalt/day. This is equivalent to 40 to 50 mg cobalt sulphate/cow/day or 5 g cobalt sulphate per 100 cows.
Selenium	In general, selenium concentrations in pastures are low (approximately 25% of requirements) and are not increased sufficiently with fertiliser so supplementation is recommended. The actual requirement for selenium is difficult to predict, because many of its functions are in conjunction with vitamin E, which is available in very large quantities in fresh forages. The general recommendation is to supply 3 to 5 mg/cow/day of supplementary selenium.
Iodine	Iodine is particularly important for reproduction and energy metabolism; however, requirements for iodine are poorly understood. There is a large variation in pasture tests and the requirement for iodine is dependent on the status of the cow, the diet and the use of iodine-based teat spray. On brassica crops it is recommended that cows are supplemented during winter and for 4 months post-calving. The most effective strategy is to spray iodine on the flank or rump (7 ml of a 5% tincture of iodine) once a week when cows have been offered a new break of crop. Although it is difficult to provide a definitive recommendation for iodine, DairyNZ recommends supplementing cows with approximately 10 mg iodine/cow/day for 4 months post-calving.

Zinc	Zinc is important for skin and hoof development, immune function and to mitigate facial eczema; however, pasture zinc concentration status is very variable and can range from 20-60 mg/kg DM across farms. Because of this variability, and because the usual level of zinc supplementation recommended is not likely to cause ill effects, DairyNZ recommends cows receive between 500 and 750 mg supplementary zinc/cow/day or approximately 1 g zinc oxide or 2-3 g zinc sulphate. Cereal by-products (e.g. wheat and oat middlings) have very high concentrations of zinc (>150 mg/kg DM) and brewers grains, distillers grains, and PKE have reasonably high concentrations (>50 mg/kg DM). The zinc content of these supplements must be taken into account in calculating likely zinc requirements of the herd as, although the recommended supplementary zinc would not make the animal sick, zinc and copper compete with each other for absorption sites in the small intestine and, therefore, high levels of zinc will lead to copper deficiency. For details on zinc requirements to mitigate facial eczema refer to the DairyNZ website: dairynz.co.nz/animal/cow-health/facial-eczema

For more details see TechNotes 2: Energy, mineral and vitamin requirements, and 13: Monitor and mitigate milk fever.

18.7 Further reading

de Veth, M. J., and E. S. Kolver. 2001. Digestion of ryegrass pasture in response to change in pH in continuous culture. Journal of Dairy Science. 84: 1449 - 1457.

Grace, N., S. Knowles, and A. Sykes. 2010. Managing mineral deficiencies in grazing livestock. Occasional Publication 10 - New Zealand Society of Animal Production: Palmerston North, New Zealand.

Holmes, C. W., I. M. Brookes, D. J. Garrick, D. D. S. Mackenzie, T. J. Parkinson, and G. F. Wilson. 2007. Milk production from pasture (2nd rev. ed). Massey University: Palmerston North, New Zealand.

Kolver, E. S., and M. J. de Veth. 2002. Prediction of ruminal pH from pasture-based diets. Journal of Dairy Science. 85: 1255 - 1266.

Kolver, E., L. D. Muller, G. A. Varga, and T. J. Cassidy. 1998. Synchronisation of ruminal degradation of supplemental carbohydrate with pasture nitrogen in lactating dairy cows. Journal of Dairy Science. 81: 2017 - 2028.

NRC. 2001. Nutrient requirements of dairy cattle (7th rev. ed). Washington, United States of American: National Academy Press.

Roche, J. R., J. K. Kay, C. V. C. Phyn, S. Meier, J. M. Lee, and C. R. Burke. 2010. Dietary structural to nonfiber carbohydrate concentration during the transition period in grazing dairy cows. Journal of Dairy Science. 93: 3671 - 3683.

The Ruminant Animal: Digestive Physiology and Nutrition. D.C. Church, ed. Illinois, United States of America: Waveland Press, Inc.

Van Amburgh, M. E., E. A. Collao-Saenz, R. J. Higgs, D. A. Ross, E. B. Recktenwalk, E. Raffrenato, L. E. Chase, T. R. Overton, J. K. Mills, and A. Foskolos. 2015. The Cornell Net Carbohydrate and Protein System: Updates to the model and evaluation of version 6.5. Journal of Dairy Science. 98: 6361 - 6380.

Wales, W. J., and P. T. Doyle. 2003. Effect of grain and straw supplementation on marginal milk-production responses and rumen fermentation of cows grazing highly digestible subterranean clover pastures. Australian Journal of Experimental Agriculture. 43: 467 - 474.