TechNote 2

Energy, mineral and vitamin requirements

IN THIS TECHNOTE

Dairy cows require energy for maintenance, milk production, reproduction, condition gain, activity, and growth. The food that the cow consumes is defined as 'gross energy'; however, the energy that is available for the cow to use is 'net energy'. This is what remains after unused feed and wastes have been excreted in the urine and faeces, or lost as heat and gasses as the feed is digested and metabolised (Figure 1). The dairy cow gets energy from the diet; and also from mobilisation of body reserves, or loss of body condition score (BCS). The later energy source is particularly important in early lactation or during a feed deficit.

2.1 Energy types

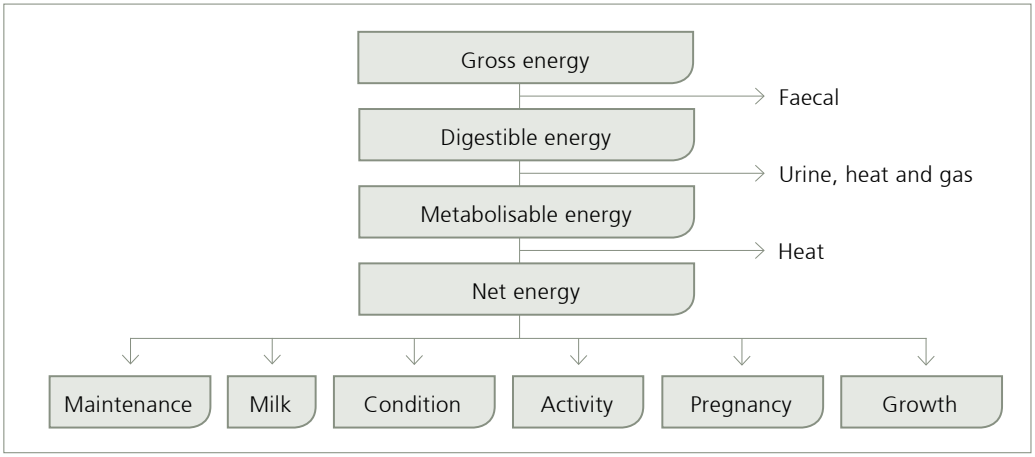
2.1.1 Gross energy (GE)

Gross energy is the total amount of energy in the food. Not all of the energy in food is available for use by the animal as some is excreted in the urine and faeces, or lost as heat and gasses as the feed is digested and metabolised.

2.1.2 Digestible energy (DE)

Digestible energy is the energy from food which can be converted into a usable energy source. Any indigestible energy is excreted by the cow. Although digestibility is not a direct measure of energy, it can be used to indicate feed quality. Generally, the greater the digestibility of a feed, the greater the energy available to the cow for metabolic activities (metabolisable energy). Digestibility is generally expressed as a percentage of the feed dry matter (%DM).

Figure 1. *Energy types and uses in the dairy cow.*



2.1.3 Metabolisable energy (ME)

Not all the energy released from digestion is available to the cow. A small proportion will be belched as gas (methane and carbon dioxide), excreted in the urine, or lost as heat during rumen fermentation. Metabolisable energy is the energy remaining for the cow to use for metabolic processes (e.g. maintenance, milk production, body condition gain, activity, pregnancy, and growth).

In New Zealand, cow energy requirements, and the energy content of feed, are expressed as MJ (megajoules) of ME (MJ ME).

For example: a 500 kg cow that is producing 2 kg milksolids requires 59 MJ ME/day for maintenance plus 154 MJ ME for milk production (see Tables 1 – 6).

Metabolisable energy is the energy available for the cow. Its calculation has already taken into account the digestibility of the feed.

2.1.4 Net energy (NE)

Although, in New Zealand, energy requirements of the cow are generally expressed as metabolisable energy, a small proportion of this energy is lost as heat during the metabolism process, and the remaining energy is the net energy. This is the most precise measure of the energy available for the cow for metabolic processes, but due to the complexities involved in measuring it, it is not commonly used in New Zealand dairy farming. In some countries cow energy requirements (and the energy content of feeds) are expressed as net energy (NE). For example: NE_L is the net energy required for lactation or NE_M is the net energy required for maintenance. These values can be converted to ME by multiplying them by an efficiency factor. For NE_L and NE_M this factor is 0.62.

Conversion from NE_L to ME

1 MJ NE_L = 0.62 MJ ME

For more details see TechNote 3: What's in a feed, and online eLearning activity: What a cow needs; dairynz.co.nz/feedright-module-1.

2.2 Energy requirements

The amount of energy required by the cow for different physiological functions depends on breed and liveweight. The quality of the feed (MJ ME) affects the efficiency of energy available within the feed.

To estimate the total amount of energy required by the cow use Tables 1 – 6. These outline the energy requirements for cows of different breeds and liveweights for maintenance, milksolids production, activity, pregnancy, growth and body condition gain or loss. The requirements in the tables are for energy "down the throat", so do not account for feed wastage or utilisation. These tables are based on an 11 MJ ME diet. Because the quality of the feed affects the efficiency of energy available, use the following calculations:

- If diet is greater than 11 MJ ME/kg DM: subtract 5% per MJ ME above 11.0 MJ ME/kg DM
- If diet is less than 11 MJ ME/kg DM: add 5% per MJ ME below 11.0 MJ ME/kg DM,

An example of how to calculate total energy requirements is provided in Table 8.

Table 1. Typical liveweights for different breeds.

Breed	LWT
Jersey	375 - 450
Kiwi cross	450 - 550
Friesian	550 - 650

Table 2. MAINTENANCE: ME required for maintenance (MJ ME/day).

Liveweight (kg)					
375	**400**	**450**	**500**	**550**	**600**
46	50	54	59	63	68

Table 3. MILKSOLIDS: ME required for milk production (MJ ME/kg MS).

Breed		
Jersey	**Kiwi cross**	**Friesian**
77	80	82

Table 4. WALKING: ME required for walking (MJ ME/km).

Terrain		
Flat	**Rolling**	**Hilly/steep**
2	3	6

Table 5. LIVEWEIGHT: ME required or saved due to LWT gain or loss (MJ ME/kg LWT change).

Lactating		Dry	
LWT Gain	**LWT Loss**	**LWT Gain**	**LWT Loss**
50	-37	72	-30

Table 6. LIVEWEIGHT: kilograms of liveweight per body condition score unit (kg/BCS)

Liveweight (kg)					
375	**400**	**450**	**500**	**550**	**600**
24	26	30	33	36	71

Table 7. PREGNANCY: ME required for pregnancy (MJ ME/day).

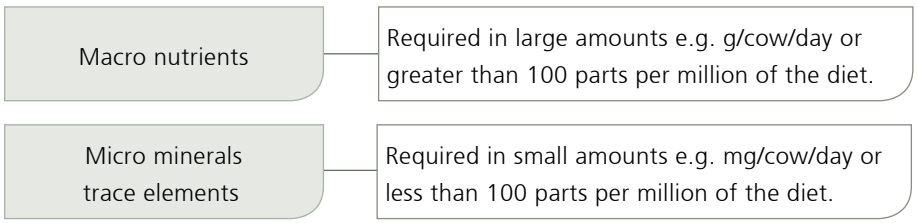
	Breed		
Weeks pre-calving	**Jersey**	**Kiwi cross**	**Friesian**
12	11	12	13
8	18	21	23
4	32	37	41
2	42	48	54

Table 8: EXAMPLE: Daily requirements of an early lactating 500 kg LWT Kiwi Cross cow, producing 2 kg MS/ day, walking 2 km on rolling terrain, losing 0.5 kg LWT/day and eating a diet averaging 12 MJ ME/kg DM.

Requirement	**MJ ME**
Maintenance	59
Walking on rolling hills for 2 km (2 km x 3 MJ ME/km)	6
Milksolids (2 kg MS x 80 MJ ME/kg MS)	160
LWT loss (0.50 kg LWT x – 37)	-19
Total MJ ME at 11.0 ME	**206**
ME requirements reduced by 5% as 12 MJ ME diet (206 x 95%)	196
Total kg DM eaten (196 ÷ 12 ME)	**16.3 kg DM**
Total kg DM offered (if utilisation was 90%)	**18.2 kg DM**

2.3 Mineral requirements and deficiencies

Minerals are essential for optimal body function. They can be grouped into two main categories:



The dairy cow needs 25 different minerals; however, many of these are required in such small quantities that they are almost never deficient in the diet.

Generally, a pasture-based diet will provide adequate quantities of all but nine of these minerals (Table 9). Supplementation with minerals that are not deficient in the diet will increase costs but will not improve animal performance (production, reproduction, and health). More details on these minerals are provided in Table 10.

Table 9. Minerals that can be deficient in grazing dairy cows.

Macro mineral	Micro mineral
Calcium	Cobalt
Magnesium	Copper
Phosphorus	Iodine
Sodium	Selenium
	Zinc

Mineral deficiencies may arise due to primary and/or secondary factors.

- **Primary:** When there are insufficient levels of the mineral in the diet e.g. copper deficiency.
- **Secondary:** Due to an interaction with another mineral. For example, absorption of a specific mineral may alter the presence or absence of a different mineral in the diet. For example: milk fever (calcium deficiency) may result from too little magnesium in the diet.
- **Primary and secondary:** Due to an inadequate supply of the mineral in the diet and an interaction with another mineral. For example: grass tetany may result from too little magnesium in the diet combined with greater than required intakes of potassium and nitrogen (which reduce magnesium absorption).

Mineral deficiencies can result in either clinical or subclinical disorders.

- **Clinical:** Signs are evident (e.g. down cow) and there is an obvious positive response to treatment.
- **Subclinical:** Signs are not obvious and a positive response to treatment may be hard to detect.

The best strategy to prevent deficiency in the herd is to identify which minerals are likely to be deficient at what stage of the season, and then supplement these appropriately. Before supplying minerals, farmers should ask if there is likely to be a deficiency in the region/herd and what is the most cost effective way to fix the deficiency.

More details on the nine minerals likely to be deficient in pasture-based systems are provided in Table 10.

For more details see TechNotes 12: Feed the transition cow appropriately, 13, 14, and 15: Monitor and mitigate milk fever, ketosis and fatty liver.

Table 10. Macro and micro minerals that may be deficient in grazing dairy cows in New Zealand.

Macro mineral	Function	Conditions prevailing where deficiencies are reported	Diagnosis of deficiency	Source of supplementation	Interfering mineral or compound
Calcium (Ca)	Development and maintenance of bone and teeth. Enables heart, nerve and muscles to function. Essential for milk production.	Dairy cows fed large amounts of maize silage or grain. Colostrum cows on pasture, especially if diet is low in magnesium and/or high in potassium. Animals treated with zinc for facial eczema.	Hypocalcaemia, or milk fever. Downer cow syndrome. Poor bone development.	Calcium supplements including: Calcium carbonate (CaCO3; ground limestone) dicalcium or monocalcium phosphate (DCP, MCP). Treatment: IV calcium borogluconate.	Phosphorus, potassium, vitamin D, zinc, oxalic acid.
Magnesium (Mg)	Very important in the prevention of milk fever as required to produce hormones that are essential for calcium absorption from the diet and mobilisation from bones.	Cold, wet spring with depressed grass growth and intakes. Grazing cows during late pregnancy and early lactation, especially if diet is high in potassium.	Hypomagnesemia. Milk fever (see above). Grass tetany: Nervousness, ears pricked, nostrils flaring, eyes alert, head held high, stiff, staggering movements. Death can result from a "tetany" where the heart muscle contracts uncontrollably.	Magnesium supplements including: magnesium oxide (MgO; CausMag) magnesium sulphate ($MgSO_4$; epsom salts) magnesium chloride ($MgCl_2$).	Potassium.
Phosphorus (P)*	Essential for bones and teeth. Vital constituent of proteins and phospholipids. Buffer in saliva, blood, and body fluids.	Poor quality hay, straw, or forage (especially in semi-arid regions). High or prolonged intakes of fodder beet.	Hypophosphataemia. Lowered intake, reduced production. Slow growth, development of rickets, poor fertility. Creeper cow syndrome and can result in haemolysis and death.	Phosphorus supplements including: Dicalcium and monocalcium phosphate (DCP, MCP). Diammonium phosphate Monosodium phosphate.	Calcium, vitamin D, phytic acid.
Sodium (Na)	Regulatory functions – saliva and body fluids. Nerve function. Important in maintaining osmotic pressure and acid-base balance in cellular membranes.	On pumice country, especially grazing lucerne. When large amounts of grain or maize silage are fed.	Suppressed appetite, poor milk production and loss of live weight. Severe signs include abnormal licking and chewing stones, gates.	Salt block, loose salt, drenching and/or fertiliser.	

**Surplus phosphorus can also cause milk fever by interfering with the hormones that control calcium absorption. Feeds high in phosphorus include PKE and maize gluten and should be limited pre-calving.*

Micro mineral (Trace element)	Function	Conditions prevailing where deficiencies are reported	Diagnosis of deficiency	Source of mineral supplementation	Interfering mineral or compound
Cobalt (Co)	Constituent of vitamin B12 and B1. Required for energy metabolism, especially in the rumen. Essential for fibre digestion and immunity.	Pumice or granite soils, especially if well drained and highly acid. High manganese in soils reduces plant cobalt uptake.	Ill-thrift, birth of weak calves, and reduced milk production ('Bush Sickness').	Apply cobalt sulphate fertiliser, supplement cobalt sulphate orally, or vitamin B12 injections.	
Copper (Cu)	Required for growth, production, and reproduction. Essential for animal health, immunity and calf viability.	Copper concentrations are generally low in pastures. High concentrations of molybdenum, sulphur and iron in pasture bind with copper in the rumen and reduce absorption.	Liver/blood test. Spring and autumn scouring, lameness, ill-thrift, faded hair, anaemia, broken bones, and poor conception rates.	Supplement with copper sulphate in water or supplementary feed, or copper oxide bullets or injections.	Molybdenum, organic and inorganic sulphur, zinc, iron.
Iodine (I)	Important for thyroid function, energy metabolism and thermoregulation. Required for milk production, protein synthesis and reproduction.	Deficiency mainly association with ingestion of goitrogenic feeds (e.g. kale) especially on limestone or sandy country and inland low rainfall areas.	Goitre (enlarged thyroid). Lower milk production.	Teat spray on flank weekly, or oil-based slow release injections.	Goitrogens.
Selenium (Se)	Important for milk production and reproduction. Essential for disease resistance, immunity and calf viability.	Levels low in annual ryegrass and browntop, especially in autumn and winter. Some soils are deficient.	White muscle disease in young stock, ill-thrift, diarrhoea, abortion, retained placenta and low milk production.	Supplement selenium orally, or slow release injections. Fertiliser applications.	Vitamin E and ferrous iron.
Zinc (Zn)	Important for skin and hoof development, immune system function, and metabolism of carbohydrates and protein.	Variable levels of zinc in pasture, across regions, farms and individual paddocks.	Facial eczema, reduced growth, poor immune function and reproductive performance.	Supplement orally with zinc oxide or zinc sulphate.	Copper.

2.4 Vitamins

Vitamins are essential organic molecules needed for immune function, absorption and metabolism of feed, reproduction, and production. The liver is the major storage organ for vitamins.

Vitamins can be divided into two categories: water-soluble and fat-soluble.

- **Water-soluble vitamins** cannot be stored in body tissue. These vitamins are typically synthesised by rumen microbes and include the B complex vitamins and vitamin C.
- **Fat-soluble vitamins** (vitamins A, D, E, and K) can be stored in large volumes in body fat and providing too much can result in toxicity. Vitamin K can be synthesized by rumen microbes so only vitamins A, D and E must be supplied by the diet.

Table 11. Vitamin functions and requirements.

Vitamin	Function/source
A	• Required for growth, milk production, reproduction, and maintaining healthy tissues. • Produced from carotene which is abundant in forages. • Supplementation not normally required in pasture-based diet.
D	• Necessary for calcium absorption, and bone formation and deposition. • Not normally present in green pastures and crops and only formed when ergosterol in plants or dehydrocholesterol in skin are irradiated with UV light. Defeciency can be a problem if cows are restricted to root crop diets (low calcium and vitamin D) or forage crop diets (can contain anti-vitamin D factors). • A deficiency of vitamin D in the presence of adequate calcium and phosphorus results in rickets. The signs of this include: swollen joints, lameness and bone fractures.
E	• A deficiency of vitamin E or selenium can lead to immune deficiency and hence increased risk of disease or white muscle disease, in which muscle degeneration can produce stiffness, uncoordinated movements, and, in severe cases, death due to heart muscle failure. • Available in large quantities in fresh forages. • Cows fed restricted diets containing conserved feeds e.g. hays, straws, maize silage, root and cereal crops, can develop vitamin E deficiencies.

2.5 Further reading

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

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