Energy in Calf Milk Replacers

Young calves require energy for normal body functions such as digestion, respiration and heat production, as well as for growth. During the first three weeks of life when starter intake is minimal, the energy available to the calf is directly proportionate to the supply of milk or milk replacer. Milk replacers are formulated to ensure they deliver enough energy (from fat and sugar) to fuel growth whilst ensuring that the energy content is not too high to help the transition onto starter feed.

Energy Requirement of the Calf – a calf requires energy for maintenance & growth

Metabolizable energy **(ME)** is the energy from the diet that actually becomes available for metabolism by tissues of the animal[1]. For calves, the total amount of ME is the sum of the ME requirement for maintenance (amount of energy used for normal body functions such as digestion, respiration, heat production) plus the ME requirement for growth (or body weight gain).

Total amount of metabolizable energy (ME) = **ME requirement for maintenance (MEm)** + **ME requirement for gain (MEg)**

Requirements for calves fed only milk or milk replacer[1]:

For young calves fed only milk, the MEm requirement is calculated as a proportion of metabolic body weight, & is calculated as:

MEm (MJ) = **(0.1 x body weight, $kg^{0.75}$) x 4.1868 Joules**

Example: **MEm for a 50 kg calf = (0.1 x $50^{0.75}$) x 4.1868 = 7.87 MJ**

The amount of ME a calf needs for growth depends on the size of the calf and the average daily gain, & is calculated as:

MEg (MJ) = **[(0.84 x body weight, $kg^{0.355}$) x (daily live weight gain, $kg/d^{1.2}$)] x 4.1868 Joules**

Example: **MEg for a 50kg calf growing at 0.7 kg/d = [(0.84 x $50^{0.355}$) x ($0.7^{1.2}$)] x 4.1868 = 9.19 MJ**

The total ME required per day is the sum of the ME requirement for maintenance (MEm) plus growth (MEg) & is calculated as:

Total ME (MJ) = **(0.1 x body $weight^{0.75}$) + [(0.84 x body $weight^{0.355}$) x (daily live weight $gain^{1.2}$)] x 4.1868**

Example: **Total ME requirement for a 50kg calf growing at 0.7 kg/d = 7.87 + 9.19 = 17.06 MJ**

Using these equations, the approximate ME requirement for calves fed only milk or milk replacer at different live weights with different daily live weight gains can be calculated (Table 1). These energy requirements make several assumptions including the temperature of the calf's environment (at between 15°C and 20°C), adequate colostrum intake and good calf health.. Factors such as a cold weather (less than 15°C) and disease challenge can increase the energy requirement.

Table 1. Energy requirement (ME) for calves fed only milk or milk replacer[2]

Body weight (kg)	Daily live weight gain (kg/d)	ME maintenance (MJ/d)	ME growth (MJ/d)	Total ME (MJ/d)
40	0.7	6.66	8.49	15.15
40	0.8	6.66	9.97	16.63
40	0.9	6.66	11.48	18.14
50	0.7	7.87	9.19	17.06
50	0.8	7.87	10.79	18.66
50	0.9	7.87	12.43	20.30
60	0.7	9.03	9.81	18.83
60	0.8	9.03	11.51	20.54
60	0.9	9.03	13.26	22.28

Requirements for calves fed milk or milk replacer plus calf starter[3]:

The ME requirement of calves fed milk or milk replacer plus calf starter differs to that of calves consuming only milk or milk replacer[3]. This is because calves fed starter utilise the ME that they consume less efficiently than the energy derived from milk or milk replacer since some of the carbohydrate and protein in the starter feed must be fermented in the rumen prior to being digested by the calf[3]. As rumen activity increases, the amount of heat produced by the calf increases as well – this heat is a by-product that is not captured by the body, so it is considered a loss[3].

Using the equations at the bottom of the page, the ME requirement for calves fed milk or milk replacer plus starter at different live weights with different daily live weight gains can be calculated (Table 2). These energy requirements assume that the temperature of the calf's environment is between 15°C and 20°C.

Table 2. Energy requirement (ME) for calves fed milk or milk replacer plus starter[2]

Body weight (kg)	Daily live weight gain (kg/d)	ME maintenance (MJ/d)	ME growth (MJ/d)	Total ME (MJ/d)
50	0.7	8.21	9.73	17.93
50	0.8	8.21	11.42	19.63
50	0.9	8.21	13.15	21.36
60	0.7	9.41	10.38	19.79
60	0.8	9.41	12.18	21.59
60	0.9	9.41	14.03	23.44
70	0.7	10.56	10.96	21.52
70	0.8	10.56	12.87	23.43
70	0.9	10.56	14.82	25.38
80	0.7	11.68	11.49	23.17
80	0.8	11.68	13.49	25.17
80	0.9	11.68	15.54	27.22

For calves fed milk or milk replacer plus starter, the MEm requirement is calculated as:

$$\text{MEm (MJ)} = (0.086 \times \text{body weight, kg}^{0.75}/0.825) \times 4.1868 \text{ Joules}$$

The amount of ME required for body weight gain is calculated as:

$$\text{MEg (MJ)} = \{[(0.84 \times \text{body weight, kg}^{0.355}) \times (\text{daily live weight gain, kg/d}^{1.2}) \times 0.69] / 0.652\} \times 4.1868$$

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Energy Supply – energy is supplied by both milk & starter feed

Energy supplied by milk replacer:

The total feed requirements of the calf depend on the age (body weight), target growth rate and environmental conditions. Volac milk replacer is carefully balanced to ensure the energy level of the milk is at the correct level for the right amount of growth. The energy provided by Volac milk replacers is given in Figure 1, whilst the energy provided at different feeding rates is given in Table 3.

Figure 1. Energy content (ME) of Volac milk replacer

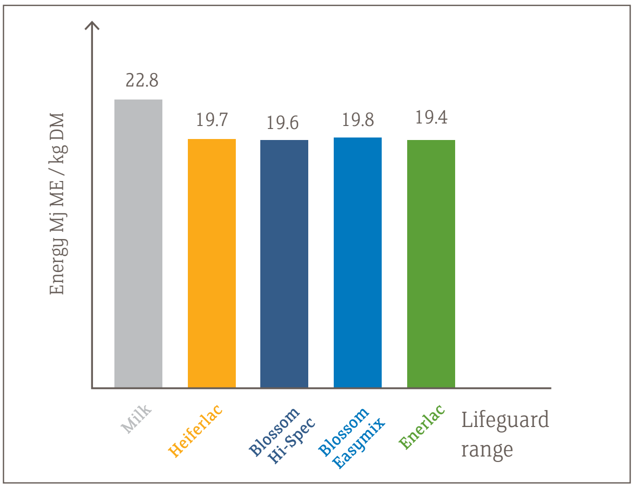


Table 3. Energy content (ME) of Volac milk replacer when fed at different concentrations & volumes

Product	ME, MJ/kg DM	Mixing Rate, g/L	Milk Volume, L/d	Total Milk Solids, g/d	Total ME, MJ/d DM+
Heiferlac	19.7	150	6 7 8	900 1050 1200	17.3 20.2 23.0
Blossom Easy Mix	19.8	125	6 7 8	750 875 1000	14.5 16.9 19.3

+Total ME MJ/d DM calculated as: ME MJ/kg DM x 97.5% DM (assume 2.5% moisture) x total milk solids

Energy supplied by starter feed:

During the first three weeks of life when starter intake is minimal, the energy available to the calf is directly proportionate to the supply of milk or milk replacer. As soon as a calf starts to increase its starter intake, the starter feed will also contribute to the energy supply. As a guide, starter intakes will begin to increase by 2 to 3 weeks of age, and by 5 weeks should increase to 0.5 kg/d. Calves should be eating 0.7 to 1 kg/d by 6 to 7 weeks, and a minimum of 1.5 kg/d at weaning.

The energy supplied via the calf starter can be estimated using the following equation (assuming starter contains 3.3 Mcal of ME/kg of DM)[3]:

ME = (ME content of starter) x (calf starter DM intake) x 4.1868 Joules

Example: **ME for a calf eating 500g starter = 3.30 x (0.5kg x 88% DM) x 4.1868 = 6.08 MJ**

These equations can be used to provide information regarding the calf's energy requirement relative to the amount of energy supplied. For example, the energy requirement of a calf with a body weight of 70 kg and a target growth rate of 0.8 kg/d = 23.43 MJ/d. Feeding 900 g milk powder per day (ME of 17.3 MJ/d) plus 500g starter per day (ME of 6.08 MJ/d) will provide a total ME of 23.38 MJ/d:

		Energy Required	Energy Supplied
Age	5 weeks	**23.43 MJ/d** (see Table 2)	
Body weight	70 kg		
Target growth rate	0.8 kg/d		
Milk powder intake	900 g/d = 17.3 MJ/d		**23.38 MJ/d**
Starter intake	500 g/d = 6.08 MJ/d		

Energy Source – both fat & lactose in milk provide valuable energy

Protein, fat and sugar can all provide energy. The energy in milk or milk replacer is predominantly derived from two sources – fat and carbohydrates. The main source of carbohydrate in milk or milk replacer is lactose (the main sugar found in mammalian milk). Sugar, in the form of lactose, is the only digestible carbohydrate for a young calf and therefore provides an important energy source.

Milk replacers typically contain 14% to 20% fat (in dry matter) compared with whole milk at 30% to 33% fat (Table 4) but the lactose content in milk also provides energy. Milk replacers have a lower fat content to help encourage the transition onto starter feed, since a high fat level can suppress starter intake[4] (see below). Milk replacers are generally comprised of about 42 to 51% lactose in dry matter, compared to dry whole milk typically ranging from 36 to 38% in lactose content. In total the proportion of ME supplied by the fat and lactose is similar for whole milk, skim and whey-based milk replacers, so all can provide valuable energy to the calf (Table 5).

Table 4. Level of fat supplied by whole milk & milk replacer (at different concentrations)

	Whole milk	Milk replacer (mixed at 125g/L)	Milk replacer (mixed at 150g/L)
Total solids %	12.5	12.5	15
Fat in dry matter %	33	14-20	14-20
Fat as fed %	4.1	1.8-2.5	2.1-3

Table 5. Energy values (ME) in dry matter supplied by different components in whole milk or milk replacer

	ME (MJ/kg DM)			ME (MJ/kg DM)
	Lactose	Protein	Fat	
Whole milk	5.53	6.02	11.18	22.7
Milk replacer (23% protein, 18% fat)	7.49	5.44	6.69	19.8
Milk replacer (25% protein, 17% fat)	7.31	5.91	6.32	19.6
Milk replacer (26% protein, 16% fat)	7.50	6.15	5.95	19.7

Energy in Milk or Milk Replacer = **Fat** + **Carbohydrate (Lactose)**

Energy Level - increasing the fat content has a negligible effect on the overall ME supplied

The energy requirement of a calf fed milk or milk replacer is calculated based on its body weight, daily live weight gain and the environmental temperature[2]. A calf expected to grow at a fast rate of gain (for example ≥0.9 kg/d) will require more energy than a calf growing at a slower rate (for example ≤0.7 kg/d). A calf also has a higher energy requirement during periods of cold weather (temperature < 15°C) since it will divert more of its energy into keeping warm (i.e. its maintenance requirement) so will need to consume more energy to maintain its growth. The best way to supply the calf with more energy is to simply feed more by increasing the volume fed or by increasing the mixing rate.

Increasing the fat content of the milk replacer (for example from 17% to 20%) has a negligible effect on the overall energy supplied compared with simply feeding more of the same (Table 6). If the fat level is increased, an equal amount of lactose must be removed from the formula (since the level of proteins and minerals are not changed) to create 'space' for the additional fat. Thus, overall an increase in fat, but a reduction in lactose, has a small effect on the total ME.

Table 6. The effect of feeding a low vs. high oil milk replacer, or feeding different volumes or concentrations of the same milk replacer, on energy intake (ME)

	ME supplied per calf per day (MJ of DM)+	
	17% oil, 25% protein, 46% lactose (19.6 ME MJ/kg DM)	20% oil, 25% protein, 43% lactose (20.3 ME MJ/kg DM)
5 litres @ 12.5%	12.0	12.4
5 litres @ 15%	14.3	14.8
6 litres @ 15%	17.2	17.8
7 litres @ 15%	20.1	20.8

+ME MJ/d DM calculated as: ME MJ/kg DM x 97.5% DM (assume 2.5% moisture) x total milk solids

Starter Intake - key for rumen development & long term performance

The intake of solid feed preweaning to stimulate rumen development is key to ensure a smooth transition around weaning. The rumen must be well developed at weaning to ensure it can utilise and digest nutrients from starter feed after weaning, and thus enable the calf to continue to grow.

It has been shown that starter consumption at weaning has a positive effect on first lactation milk production; each additional 1kg of calf starter dry matter intake at 8 weeks of age resulted in 8.2 kg more milk in the first lactation 305 day milk yield[5]. Similarly, a recent study has found that starter ME intake had a positive effect on 305 day fat and protein production, and that the 6 and 8 week combined ME intake from both milk replacer and starter had a positive effect on 305 day milk fat and protein production in lactation 1[6]. These studies highlight the importance of a combination of both milk replacer and starter protein and ME on first lactation performance.

Fat Level - a high fat content can suppress starter intake

By supplying more lactose and less fat, calf milk replacers typically stimulate the earlier intake of solid feed. A high fat content (>20%) has been shown to suppress starter intake and digestion resulting in less growth before weaning (Table 7)[4]. This study fed Holstein bull calves milk replacer (27% crude protein) with fat levels of either 14, 17, 20 or 23% on a dry matter basis[4]. Increasing the fat level from 14 to 23% resulted in only a small increase in ME from 19.7 to 21.8 MJ/kg (Table 7). Calves were fed 681 g milk powder per day and offered pelleted calf starter and fresh water ad libitum. The apparent digestibility of dry matter and fat decreased as the concentration of the fat increased from 14 to 23% in the milk replacer (Table 7).

Preweaning starter intake was lowest for calves fed milk replacer with both 14% and 23% fat. This reduction in digestion and starter intake was thought to contribute to the lower preweaning (day 0 to 28) and overall (day 0 to 56) average daily gain seen in calves fed the milk replacer with higher fat levels of 23%. These data show that a 27% crude protein, 17% fat milk replacer with 55 g of crude protein / Mcal of ME maximised preweaning average daily gain[4].

It is important to note that in this study the calves were fed 681 g milk solids per day – these calves would have been driven by hunger to eat starter feed due to the low amount of milk solids provided. It is more typical to feed calves a minimum of 750 g milk solids per day – increasing the amount of milk solids provided per day suppresses starter intake since calves will be fulfilled by the milk feed and not driven by hunger to eat starter[7]. It is therefore likely that feeding a high volume of a high fat milk replacer would further suppress starter intake, compared to feeding a low volume of a high fat milk replacer as per the study (Table 7)[4].

Table 7. Effect of increasing fat level in milk replacer from 14% to 23% on calf starter intake & average daily gain of Holstein bull calves[4]

	14% fat MR	17% fat MR	20% fat MR	23% fat MR
Fat % of DM	14.4	17.5	20.6	23.7
Crude protein % of DM	27	27	27	27
ME, MJ/kg	19.7	20.5	21.3	21.8
Digestibility DM, g/g	0.83	0.83	0.81	0.80
Starter intake, kg/d				
0-28d	0.15	0.19	0.19	0.16
28-56d	1.55	1.49	1.53	1.38
Average daily gain, kg/d				
0-28 d	0.33	0.36	0.35	0.32
0-56 d	0.53	0.54	0.54	0.49

Fat Level – a high fat content can increase fat deposition

The crude protein and energy intake from milk replacer greatly affects calf growth and carcass protein and fat deposition[4]. Carcass protein increases and fat decreases as the ratio of protein to energy increases in calf diets[8]. Therefore, the ratio of protein to fat must be balanced to achieve protein deposition and limit fat deposition in replacement heifers. A study has fed Holstein bull calves three different milk replacer treatments to deliver low fat (15% of DM), medium fat (22% of DM) or high fat (31% of DM) (Table 8)[9]. Despite a difference in fat level, the varying lactose level in the three milk replacers meant that the diets provided a similar level of protein and energy, resulting in a similar empty body weight gain between the groups (Table 8). Calves fed milk replacer with 15% fat and 22% fat both had an empty body weight gain of 0.61 kg/d; but the calves offered a higher fat (31%) milk replacer had more fat gain. This study concluded that increasing the fat level above 15% has no beneficial purpose (in terms of faster growth) unless additional fat deposition is required in an animal[9].

Table 8. Effect of varying carbohydrate (lactose) & fat content of milk replacer on body composition of Holstein bull calves[9]

	Fat 15% MR	Fat 22% MR	Fat 31% MR
Carbohydrate (lactose) %	55.3	46.7	35.4
ME (MJ/kg)	18	20	22
Empty body weight gain (kg/d)	0.61	0.61	0.65
Body CP gain (kg)	5.8	5.7	6.1
Body fat gain (kg)	3.9	5.1	6.1

Feeding a high plane of nutrition increases mammary growth & development

Increasing the energy and protein intake (by feeding a high level of a high protein, low-fat milk replacer) has been shown to increase mammary growth and development. A study has compared feeding Holstein calves up to 8 weeks, either a high plane of nutrition of a high protein, low-fat milk replacer (30% crude protein, 16% fat) or a low plane of nutrition using a milk replacer with a higher fat level (21% crude protein, 21% fat)[10]. Increasing the fat level from 16 to 21%, resulted in only a small increase in ME from 18.4 to 19.7 MJ per kg of DM (Table 9). Calves fed the high protein, low-fat milk replacer had greater total mammary gland mass, and 3 times the amount of mammary parenchyma (defined as the breast tissue, excluding the connective tissue) at 8 weeks of age, compared with calves fed milk replacer with a higher fat level (Table 9)[10]. The extent of development of mammary parenchyma in heifers is important because the number of mammary cells is a major factor limiting milk production.

Table 9. Effect of plane of nutrition (2 to 8 weeks) on mammary gland development of female Holstein calves aged 8 weeks[10]

	Low plane of nutrition	High plane of nutrition
Crude protein %	21.3	30.3
Fat %	21.3	15.9
ME per kg DM of milk replacer	19.7 MJ	18.4 MJ
Milk replacer intake on DM basis	1.1% of BW (mixed @ 11.8%)	2% of BW (mixed @ 14.1%)
Total gland, g/100 kg of BW	181	255
Parenchyma, g/100 kg of BW	1.9	6.2

Fat Source – key for digestion and health

The fat in whole milk is highly digestible, and well formulated milk replacers contain a blend of fat sources which are designed to be well digested by the calf and provide energy and nutrients to help maintain good health and growth. Fats are comprised of short-chain, medium-chain and long-chain fatty acids. The length of the chain is determined by its structure and the number of carbon atoms present within that structure (i.e. short-chain fatty acids have less than 6 carbons, whilst long-chain fatty acids have 13 or more carbons); the structure determines how it is digested and absorbed. Initially the newborn calf will rely on the breakdown of the short-chain and medium-chain fatty acids for its energy source, with the digestion of long chain fatty acids becoming more efficient after about 3 weeks.

Fatty acids are not only a fuel source for the calf, but they also carry out important anti-microbial roles. Milk fat exists in droplets of oil surrounded by a membrane containing other fats (phospholipids and sphingolipids) – it is these that support calf gut maturation and help to fight off damaging bacteria.

The fat in Volac milk replacer is supplied by Imunopro ("concentrated whey protein and phospholipid base") as well as a proportion in the form of high quality vegetable oils (palm and coconut oil). Imunopro retains the natural phospholipids found in the whey fraction of whole milk – these natural phoshoplipids are key in supporting gut maturation. The addition of a blend of palm and coconut oil to Volac milk replacer ensures an optimum fatty acid profile in the finished product. Coconut oil is a good source of the short to medium-chain fatty acids – these fatty acids protect against gram negative bacteria (i.e. E. Coli and Salmonella), whilst the medium-chain protect against gram positive bacteria (Clostridia). The blend of palm and coconut oil ensures a good source of the short to medium

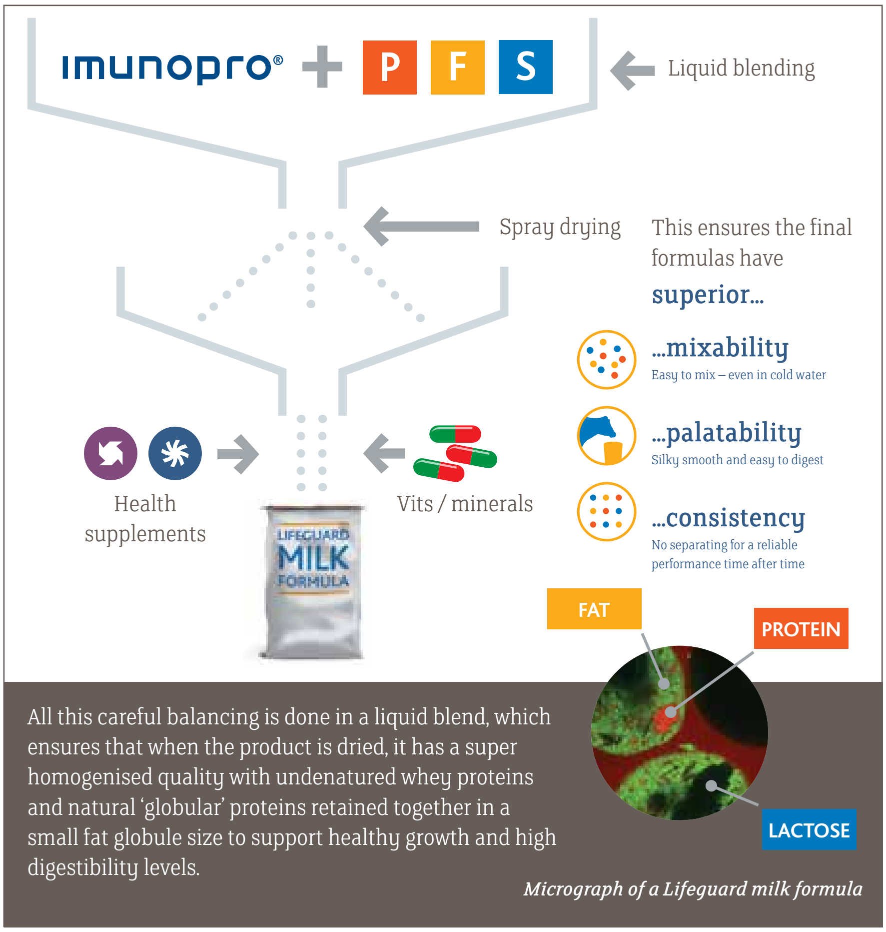
chain fatty acids, but the addition of butyrate (a short-chain fatty acid that is found in whole milk) to Volac milk replacer also adds to the balance. Butyrate is one of the best evidenced feed supplements in the world, and is also used in human medicine. It is very beneficial to the calf – and has been proven to help with gut growth and development, and help maintain a healthy gut environment[11].

Fat Processing & Incorporation – homogenisation & small fat globule size increases digestibility

The digestibility of fat in a milk replacer has a significant impact on the energy delivered to the calf, with fat processing a key determinant. Homogenization of fat (where milk fat globules are reduced in size and dispersed uniformly) improves its digestibility[12]. For example, homogenised coconut fat with added lecithin has been shown to be 90% digestible, while the same coconut fat in the unhomogenized state was only 66% digested when fed to calves[13]. The fat globule in cow's milk is small, varying from 0.1 to 10 µ in diameter, making it highly digestible. The homogenisation of the liquid stream of imunopro and vegetable fats used in Volac milk replacer results in a small fat globule making it highly digestible.

The technology used to incorporate the fat is also important since fat is not soluble in water by itself. The vegetable fats in Volac milk replacer are added to the liquid imunopro before the drying process – this combines the fat with the whey proteins, and following homogenisation of the liquid stream, results in small evenly dispersed particles, that readily dissolve in water.

Figure 2. Processing of Volac milk replacer



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Lactose Level – lactose is present in the milk of most mammals & is a readily digestible source of glucose

Lactose is the major carbohydrate in milk, present in the milk of most mammals. Milk fed calves have an excellent ability to digest lactose – it is broken down in the small intestine of the neonate into smaller monosaccharides (glucose and galactose)[14]. Lactose is a major, readily digestible source of glucose which provides energy for the young calf.

The lactose level in a milk replacer can be calculated crudely by difference:

As Fed Basis

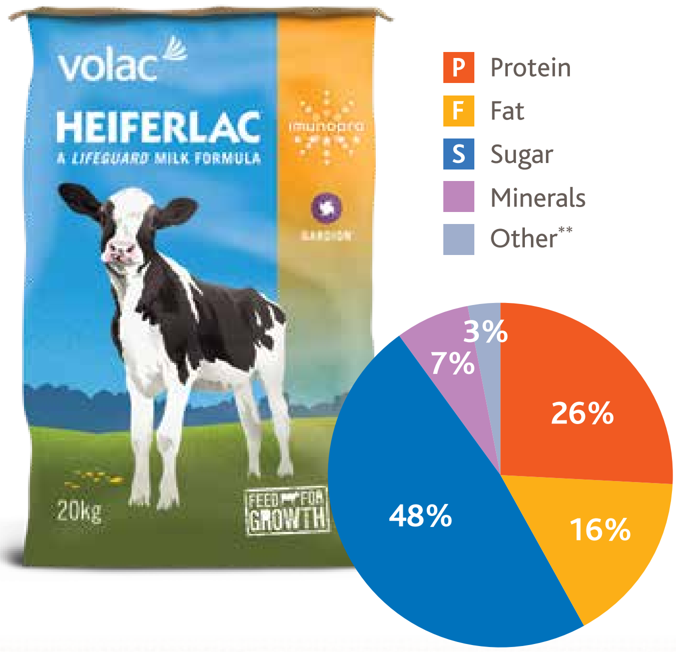
Lactose = 100 – (moisture % + crude protein % + fat % + ash %)

Dry Matter Basis

Lactose = 100 – (crude protein % + fat % + ash %)

Crude protein and fat are listed on the label on an 'as fed basis' (not as dry matter). Therefore, assuming moisture is 3%, the lactose can be calculated as:

100 – (3 + 26 + 16 + 7) = 48%.



Reference values for the upper limit of lactose in milk replacer are not well established. One study has suggested that the maximum limit of lactose in a milk replacer should not exceed 10g per kg of BW[14]. Calves were fed milk replacer containing either 10, 13 or 16 g lactose per kg BW per day[14]. The addition of lactose at 13 and 16 g per kg BW resulted in a rapid fall of faecal consistency and therefore it was concluded that the maximum limit of lactose in the milk replacer diet should not exceed 10g per kg BW[14].

Feeding a high plane of nutrition (typically 900 g milk powder per day) using a high quality milk replacer with a lactose level of 48%, would provide the calf with 419 g lactose per day (900 g x 48% x 97% DM = 419 g per day). Supplying 419 g of lactose per day would equate to approximately 9.3 g lactose per kg BW for a 45 kg calf, 7.6 g lactose per kg BW (55 kg calf), and 6.4 g lactose per kg BW (65 kg calf). Therefore, using a milk replacer with a lactose content of approximately 48% (as per the example above) and supplying the calf with around 419 g lactose per day does not exceed the suggested lactose tolerance level (10 g per kg BW[14]) for a young calf.

Osmolality – avoid offering milk with an osmolality of >600 mOsm/L

Osmolality can be defined as the concentration of solute particles in a solution; i.e. it refers to how concentrated a solution is. Whole milk is typically 12.5% total solids which equates to an osmolality of about 300 mOsm/L which is optimal for absorption and digestion of nutrients. The osmolality of milk replacers mixed at 12.5% to 15% total solids typically ranges from 400 to 600 mOsm/L. Volac milk replacer mixed at 12.5% solids (125g milk powder per litre of mixed milk) has an osmolality of about 390 mOsm/L (range 350 to 420 mOsm/L).

Greatly increasing or decreasing the osmolality of milk can alter the digestibility and increase the risk of digestive tract upsets, primarily due to the impact on the rate of abomasal emptying[15]. Reference values for the upper limit of osmolality of a milk replacer are not well established but it has been suggested that fluids with an osmolality of greater than 600 mOsm/l should be offered with caution, and they should never be provided when water is not available[16]. In support of this, recent data has shown that increasing the osmolality of whole milk (by adding milk replacer) up to 533 mOsm/l had no effect on the rate of abomasal emptying, nutrient digestibility, or fecal score (Table 10)[17]. Furthermore, it has been suggested that abomasal bloat problems (due to a reduced rate of abomasal emptying) are often associated with a total solid content well above 15%, and an osmolality greater than 650 mOsm/l[15]. Taken together, these data show that feeding milk replacer with an osmolality up to around 600 mOsm/l does not negatively impact on calf growth or performance.

Table 10. Increasing the total solid content of whole milk did not affect passage rate or fecal scores of Holstein crossbred male calves[17]

	Total solids in whole milk			
	13.5%	16.1%	18.2%	20.4%
Whole milk + milk replacer, g of DM per day	810	958	1064	1142
Average daily gain, g per d	694	876	852	903
Osmolality, mOsm/l	265	351	439	533

Two factors determine the osmolality of milk replacer: 1) the concentration and 2) the formulation. Greatly decreasing or increasing the mixing rate (as well as adding additives) will alter the osmolality. In terms of the formulation, the main contributory factors are the level of lactose and dextrose (a corn sugar) and ash (i.e. sodium, potassium, chloride and calcium). However, a study looking at the impact of increasing lactose content of milk replacer from 9.7 to 16.2 g per kg BW found only a small increase in digesta osmolality (range from 300 to 375 mOsm/l) with increasing lactose[14]. In summary, using a high-quality milk replacer (mixed at 12.5% to 15% total solids) with a lactose level of around of around 48% (on an 'as fed basis'), and a low ash content (less than 8%) will help ensure the osmolality of the mixed milk remains less than the recommended maximum of 600 mOsm/L[16].

Top Points:

1. Feed calves enough milk to supply the energy required for both maintenance & the target growth rate
2. Lactose in milk & milk replacer is a readily digestible source of glucose providing an important energy source
3. Increasing the fat content of milk replacer has a negligible effect on total energy supplied
4. Increase the energy supply to a calf (during cold weather or to increase growth rate) by increasing the volume fed or increasing the mixing rate
5. A milk replacer with a high fat content (>20% fat) can suppress starter intake
6. A combination of both milk replacer & starter protein & ME is key for first lactation performance
7. The protein & fat content of a milk replacer must be balanced to avoid excessive fat deposition
8. Feeding a high level (of a high protein, low fat milk replacer) increases mammary growth & development
9. Volac milk replacer is formulated to contain a blend of fat sources which are designed to be well digested & provide energy & nutrients to help maintain good health & growth
10. The vegetable fats in Volac milk replacer are incorporated into the liquid imunopro before the drying process to ensure the fat is combined with the protein enhancing digestibility
11. A high-quality milk replacer with a lactose level of 48% & a low ash content (<8%), mixed at 12.5 to 15% solids, will help minimise osmolality

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