Technical bulletin

Protein in Calf Milk Replacers

Ir. Mascha de Wit
Nutritionist R&D Department

T: +31 (0)413 37 26 00
F: +31 (0)413 35 31 36
A: P.O. Box 441, NL-5460 AK Veghel
I: www.nutrifeed.com

Nutrifeed, everything to help you grow
1. Introduction

Protein is an important nutrient in feed for several reasons:

- Protein is the major structural component for body weight gain (muscles or meat).
- Protein supplies the animal amino acids as they are the basic components of proteins.
- Protein plays an important role as energy source (Boekholt and Schreurs, 1994).

The main protein source in Calf Milk Replacers (CMR) has to be dairy based. So called co stream products from the cheese (whey) or butter (skimmed milk) production were economic and very effective for rearing and fattening calves. Unfortunately, the cost price for dairy based proteins has made an accelerated increase. The inclusion of alternative proteins in milk replacers has therefore widely expanded in order to decrease the cost price.

At Holland Dairy Feed two spray dryers dry dairy streams, deriving from several Campina operations, into high quality dairy ingredients. These powders are the main components in the calf milk replacers and concentrates of Nutrifeed for young animals. Dairy proteins are highly valued due to the well-balanced amino acid profile, high digestibility, absence of anti nutritional factors and presence of bio-active peptides. Besides dairy proteins, for more economic CMR products, Nutrifeed applies highly digestible vegetable proteins while maintaining the technical performances of rearing calves. Since 2006 Nutrifeed has the ability to spray dry highly digestible wheat protein together with the fat combination. This mixture of coconut and palm oil together with wheat protein is encapsulated by whey protein. This ‘co spray drying’ guarantees optimal physical properties for calf milk replacers, suitable for all different feeding methods!

To provide an overview of this valuable nutrient, the protein structure, protein digestion, optimal protein sources and protein levels in CMR are reported in this technical bulletin.
2. Protein structure

Amino acids are the basic protein components. Around 20 different amino acids exist and some are essential for animals (cysteine, lysine, methionine, threonine and tryptophane). The animal is not capable of synthesizing these amino acids itself (Gerrits, 1996). For this reason the amount of essential amino acids are according to the requirements for calves in Nutrifeed CMR products! The basic protein structure, is a sequence of a chain of amino acids, as explained in Figure 1. An overview of amino acid compositions in dairy and vegetable protein sources and the amino acid requirements for a young calf are shown in Table 1.

![Figure 1 Primary protein structure](image)

The difference between amino acids is represented in the side chain (see Figure 1 where the side chain is represented in the ‘R group’). Amino acids are classified, based on the properties of the side chain, into four groups. The amino acids behave like ‘a weak acid’, ‘a weak base’, ‘a hydrophile’ or ‘a hydrophobe’ based on this side chain. Amino acids play an important role in maintaining physiological processes in the body (feed digestion, hormones, reproduction etc.). To create a protein (protein synthesis), carboxyl and amino groups of the amino acids undergo reactions to bind together (peptide bond). The different amino acids bind together to form a specific sequence of a chain. This specific sequence of amino acids makes the difference between proteins! In this way, vegetable proteins can be synthesized by the animal into animal proteins (muscles or meat and milk). In Table 1 the amino acid composition of dairy and vegetable ingredients is reported. Especially SMP and WPC contain sufficient amounts of amino acids according to the requirements for a young calf.

### Table 1 The AA composition of dairy and vegetable ingredients commonly used in CMR are given as well as the AA profile requirements for a young calf (Nutrifeed; Tanan, 2005).

<table>
<thead>
<tr>
<th>% AA / % protein (N*6.25)</th>
<th>SMP</th>
<th>WPC</th>
<th>SPC</th>
<th>Wheat gluten</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threonine</td>
<td>4.4</td>
<td>7.9</td>
<td>4.2</td>
<td>2.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Valine</td>
<td>6.4</td>
<td>6.9</td>
<td>5.2</td>
<td>4.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Methionine + Cystine</td>
<td>3.5</td>
<td>4.8</td>
<td>3.2</td>
<td>3.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>5.2</td>
<td>7.2</td>
<td>5.0</td>
<td>3.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Leucine</td>
<td>9.8</td>
<td>11.4</td>
<td>8.0</td>
<td>6.9</td>
<td>8.4</td>
</tr>
<tr>
<td>Phenylalanine + Tyrosine</td>
<td>9.8</td>
<td>7.0</td>
<td>8.8</td>
<td>8.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Lysine</td>
<td>8.2</td>
<td>9.8</td>
<td>6.5</td>
<td>1.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Histidine</td>
<td>2.8</td>
<td>2.1</td>
<td>2.6</td>
<td>2.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Arginine</td>
<td>3.6</td>
<td>2.7</td>
<td>7.3</td>
<td>3.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.3</td>
<td>2.2</td>
<td>1.3</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

SMP = Skimmed Milk Powder, WPC = Whey Protein Concentrate and SPC = Soya Protein Concentrate.

3. Protein sources

3.1 Dairy protein sources
Bovine milk is a complex product containing water (87%) and solid components (13%). The solid components in milk are fat, proteins, lactose and minerals. The distribution of these components in milk varies between cows mainly due to differences in breed and diet. Proteins are large molecules constructed by different sequences of amino acids. The major protein fraction in milk is casein (80%). Casein is predominantly present in skimmed milk powder and buttermilk. Lactoalbumin, lactoglobulin, immunoglobulin, albumin and lactoferrin (together 20%) are the protein components of the whey powder and the Whey Protein Concentrate (WPC).

As described in paragraph 4 (protein digestion), casein and whey passage through the abomasum is different. Casein protein is slowly pre-digested and released in the small intestine after approximately 8 hours. Whey proteins have a retention time of only 1.5 hours in the abomasum and are therefore digested at a much quicker rate (Rinia, 2006). It has been suggested that the curd formation and the slower transit time of casein is beneficial to digestion because of the slow release of nutrients, although more recent research has shown no improvement of curd formation on digestibility or performance in calves. Lammers et al. (1998) showed that calves fed a CMR containing skimmed milk performed more poorly than did calves fed milk replacers with higher proportions of WPC, and found that the clotting effect of casein was not required for optimal performance. Based on that research, whey proteins can be substituted successfully for skimmed milk powder (Tanan, 2005). In addition it can be hypothesized that the faster transit time in the abomasum of whey proteins, leaves the calf less saturated and stimulates the ingestion of other feedstuffs like calf starter concentrate and roughage (see Figure 2). Enhanced intake levels of calf starter and roughage are associated with advanced rumen development and allow early weaning (Nutrifeed trials FP193 and FP195).

Figure 2 Results roughage intake Nutrifeed trial ‘04 with SMP or Whey based calf milk replacer

![Figure 2](image-url)
Weaning of rearing calves normally occurs when the daily intake of at least one kilo concentrate per calf per day has been reached. In Figure 3 the development of a ‘monogastric’ calf to a ruminant is shown. A combination of water, roughage (hay and maize) and concentrate (commercial calf starter concentrate) are required to obtain the optimal rumen development and feed substrate for the fermentation process by rumen microbes!

**Figure 3 Rumen, reticulum, omasum and abomasum development in calves**

The principle ingredient of CMR formulas in the past has been dried skim milk. Besides the shorter retention time, also the increased prices and increased demands from the food sector have shifted the usage to whey powder, delactosed whey powder and whey protein concentrate as the primary dairy protein sources in calf milk replacers the last 20 years (Tanan, 2005).

In 2006 Nutrifeed successfully developed the Kalvolac Unique concept as alternative for the increased Skimmed Milk Powder (SMP) prices. At least one third of the proteins present in Kalvolac Unique are casein proteins. The casein proteins are digested by calves over a period of 6-8 hours due to curding in the abomasum, whilst whey proteins can be readily absorbed within 1.5 hours transition time. The benefit of this unique ratio of proteins present in Kalvolac Unique is that the calf feels less saturated and is therefore stimulated to ingest more roughage and concentrate. In this way the rumen is stimulated to develop at a young age, which is ideal for rearing calves. A trial at our research facility resulted in healthy calves and an average daily gain of 900 gram per day. Eight field trials under different circumstances (bucket versus different automatic feeding machines, normal versus ad libertum feeding scheme) confirmed all the positive expectations in relation to the milk intake, average daily gain and health. The strength for Nutrifeed is that caseinate is directly available from DMV International.

### 3.2 Vegetable protein sources

In the European market there are two vegetable protein sources commonly used as dairy protein alternatives, soy protein concentrate and hydrolysed wheat protein. These products must ensure suitability for liquid application and there must be the lowest possible anti-nutritional factors as well (Tanan, 2005). Anti-Nutritional Factors (ANFs) are classified as non-fibrous natural substances having negative effects on growth or health of animals. ANFs provide the plant with a natural protection against attacks of bacteria, insects, birds and herbivores as well (Blok et al., 1993). ANFs can be classified based on their effects on the nutritional value of feed and on the biological response in the animal. For the (vegetable) protein, ANFs can have a depressive effect on protein digestion and on the utilisation of protein. The ‘responsible’ ANFs for these effects are trypsin and chymotrypsin inhibitors, lectins, phenolic compounds or saponins.
Soy protein concentrate is derived from soybean meal by a number of steps. Through these steps the ANFs are minimal (trypsin inhibitor, lectins, antigenic proteins and alkaloids). Depending on the sources, the digestibility of soy protein concentrate is in between 0.84-0.92. Hydrolysed wheat protein (see Figure 4) is an interesting by product from the wheat starch industry. Wheat protein needs to be processed further to be suitable for milk replacer application, because the product is viscoelastic and insoluble. After these extra processing steps, hydrolysed wheat protein does contain minimal ANFs (trypsin inhibitor) and is highly digestible (0.87-0.94) (Tanan, 2005).

Figure 4 Soya (Plantae Magnoliophyta Magnoliopsida) and Wheat (Plantae Magnoliophyta Liliopsida)

A lot of research, concerning the inclusion of plant proteins in CMR, is performed worldwide. Many times it is concluded that inclusion of plant proteins in CMR frequently causes changes in digestion, increased volumes of faeces, decreased nutrient digestibility (Montagne et al., 2001), decreased growth and decreased feed efficiency (Drackley et al., 2005).

Glutamine is an amino acid with a supportive role in intestinal integrity and functionality. This amino acid should overcome the altered intestinal morphology caused by soy protein concentrate in the CMR. Unfortunately, addition of glutamine did not improve the intestinal morphology to a soy protein concentrate CMR (Drackley et al., 2005). However, the quality of a soy containing CMR can be further improved if the limiting amino acids are added as well (Kanjanapruthipong, 1998). This is performed in all economical CMR products from Nutrifeed to fulfil the amino acid requirements of a rearing calf. Inclusion of 33% wheat gluten of the protein content in a calf milk replacer resulted in comparable technical performances compared to 100% dairy protein milk replacer (Terui et al., 1996).

The high amount of protein combined with minimal anti-nutritional factors makes both soy protein concentrate and wheat gluten good supplements for dairy protein in economically CMR products.
3.3 Animal protein sources other than dairy

The addition of animal protein sources is also widely reported in the literature. Blood plasma, red blood cells and fish meal are some examples of animal protein sources commonly used as dairy protein alternatives. In December 2000 the European legislation banned all animal protein sources in feed, due to the Bovine Spongiforme Encefalopathie (BSE) outbreak. At the moment these restriction are eased, but Nutrifeed continued with primary dairy proteins and high digestible vegetable proteins!

4. Protein digestion

In neonatal calves, colostrum has to be the first feed supply. Colostrum is defined as the lacteal secretions from the mammary gland during the first 24 hours after birth. Colostrum provides the newborns concentrated nutrients and energy. This results in drastic morphological and functional changes of the Gastro Intestinal Tract (GIT) and development of the passive immunity (Margerison and Downey, 2005). Bovine colostrum contains besides cells (lactocytes, erythrocytes, leukocytes), nutrients (essential fatty and amino acids), minerals, trace elements, bioactive peptides (lactoferrin, lactoperoxidase, immunoglobulins) and (pre)-vitamins. Most components of colostrum decline rapidly after onset of lactation in cows. In Table 3 the composition of bovine colostrum and milk is given.

Table 3 Composition of bovine colostrum and milk (Foley and Otterby, 1978)

<table>
<thead>
<tr>
<th></th>
<th>1st colostrum</th>
<th>2nd colostrum</th>
<th>3rd colostrum</th>
<th>bovine milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids, %</td>
<td>23.9</td>
<td>17.9</td>
<td>14.1</td>
<td>12.9</td>
</tr>
<tr>
<td>Fat, %</td>
<td>6.7</td>
<td>5.4</td>
<td>3.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Protein, %</td>
<td>14.0</td>
<td>8.4</td>
<td>5.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>2.7</td>
<td>3.9</td>
<td>4.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Vitamin A, µg/dl</td>
<td>295</td>
<td>113</td>
<td>47</td>
<td>34</td>
</tr>
<tr>
<td>Ig’s, mg/ml</td>
<td>6.0</td>
<td>2.4</td>
<td>1.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Neonatal calves are primary monogastric animals compared to mature ruminants. Milk will flow into the abomasum directly by the esophageal groove. The abomasum is well developed to maximize milk digestion in neonatal calves.

Casein protein in milk starts to react with chymosine from the rennet when the CMR enters the abomasum. This forms, under the influence of calcium ions, the calcium-paracasein-complex. Due to the clotting, the casein is better accessible to the protein splitting enzyme kathepsin to split the protein in smaller polypeptides (‘pre-digestion’). After 3 weeks rennet-kathepsine digestion is taken over by hydrochloric acid- pepsin digestion in the abomasum of calves. The casein curd is released in the small intestine after approximately 8 hours. Whey proteins in milk, which are non-clotting, have a retention time of only 1.5 hours in the abomasum and are therefore digested at a much quicker rate compared to casein proteins (Rinia, 2006). After the abomasum, both casein and whey proteins are transported to the small intestine through the pyloric sphincter. In the small intestine the nutrients are further digested under influence of hormones, enzymes and emulsification. Protein digestion, or proteolysis, is the degradation of proteins into the different amino acids. The abomasum produces gastric juice including chymosine en pepsins to ‘pre-digest’ proteins. The pancreas and small intestine produce different enzymes to degrade the proteins (trypsin, chymotrypsin and peptidases) (Guilloteau and Zabielski, 2005). After proteolysis the different amino acids pass through the small intestine’s wall into the blood system. Amino acids can be ‘recycled’ as component in the protein synthesis (muscles, hormones, enzymes) or can be used as energy source.
5. Protein levels in CMR

The amount of protein in a rearing calf diet must be adequate for amino acids requirements and growth (NRC, 1989). On the other hand, overfeeding leads to a high cost price and elevated nitrogen secretion which negatively influences the environment. Research with different amounts of protein in CMR, with similar initial energy intake, demonstrates that the protein content markedly affects components of body growth (Blome et al., 2003). An overview of research demonstrates the ability to manipulate the composition of gain by different levels of protein in a diet (Amburgh and Drackley, 2005). In other research a protein and fat deposition in preruminant calves was measured. By increasing protein intake, the efficiency of the utilization of the digested protein was low. Only 30% of the extra ingested protein was deposited in the animal. In this research the maximum protein deposition capacity was reached at 24%. Above this 24% protein (100% dairy) in the diet, the capacity of protein deposition was lower which results in an inefficient protein use in the calf (Gerrits, 1996). Bovine milk contains 12.9% solids, depending on lactation state and breed of the cow (see also Table 2). The amount of protein is 24% of the solid content. The growth and body composition of dairy calves fed milk replacers containing different amounts of protein was studied at two feeding rates (Bartlett et al., 2006). The protein level varied from 16 to 26 percent in the milk replacer. The water and protein gain in the empty body increased and the fat gain in the empty body decreased linearly when the protein content increased in the CMR. However, the highest protein efficiency was performed at 22% protein (whey based) in the milk replacer. In the literature the ideal protein content in calf milk replacers is 22% according to the requirements of a rearing calf (NRC, 1989).

In rearing calves the growth has to be optimal instead of maximum for adequate rumen and udder development. Calves develop their rumen properly, when a combination of roughage, concentrate and water is provided (Coverdale et al., 2004; Heinrichs and Lesmeister, 2005). At weaning (between eight and ten weeks after birth) the rumen must be fully developed to minimize a post weaning check. CMR products, with an optimal level of protein as well as optimal protein sources, are very important for a well balanced start of rearing calves. Nutrifeed has the know-how in this field for over 30 years now, to select the highest quality protein sources from dairy as well as vegetable origin!
6. References


