Protein efficiency in dairy cows: a promising future for phytogenics

In dairy milk production attention is mostly concentrated on efficiency. On the one hand there is talk of efficiency of animal production and on the other, there is talk about feed efficiency.

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Farmers of today invest a lot in high quality genetics – it is much more important to maintain very high quality rations as well, hence making it possible to fully exploit the genetic potential of dairy cows.

Phytogenic (plant-based) feed additives (PFA) have been able to substantially up-value ruminant rations for years – and their future is promising.

Milk and protein synthesis in the udder

Dairy cows are true top athletes. To produce 1kg of milk, about 500 litres of blood flow through the udder, which means that for today's high-performance cows about 20,000 litres of blood are required. Of course, these processes represent a great physiological strain for lactating cows – accompanied by special feeding requirements that must be met in the best possible way.

The udder is a very big organ weighing around 50kg, including milk and blood. The mammary gland comprises secreting tissue and connective tissue, the former representing the main limiting factor for milk production.

The secretory cells (alveoli) synthesise the milk which is stored in the lumen of each alveoli. Clusters of alveoli that drain to a common duct form a lobule, from which the milk is squeezed into the milk duct, hence to the gland cistern. Once the cistern is filled, the milk remains in the lobule.

The milk protein (largely casein, and to a smaller extent whey protein) is synthesised from blood derived amino acids and peptides. The main part of casein occurs in the form of so-called casein micelles (small spherical aggregates, each containing thousands of casein molecules), whose aggregation takes place in the Golgi vesicles of the secretory cells in presence of calcium and phosphorus.

In addition to being processed, casein plays an important role from a nutritional point of view due to its favourable amino acid pattern.

The milk protein content is influenced by endogenous and exogenous factors such as genetic potential, lactation stage, feeding and husbandry.

But before the milk protein is synthesised, it is the cow that must first be supplied with sufficient protein.

Protein supply in ruminants

The protein supply in dairy cows is ensured by a sufficient content of crude protein in the ration and the amount of available protein in the small intestine.

Crude protein is broken down to ammonia in the rumen with the help of microbes, which then convert the ammonia into precious microbial protein, given that the microbes are provided with energy from fermentable carbohydrates.

If there is a crude protein surplus and/or energy deficiency, an ammonia surplus is produced which must be detoxified via the liver in the form of urea, being measurable in the blood, urine and milk. The decisive factor is the amount of protein that reaches the small intestine, where it is available to the animal.

This amount mainly consists of microbial protein (50-75%) and to a lesser extent of undegradable protein, which passes the rumen and reaches the small intestine directly.

This explains the necessity to feed high-performance dairy cows pm a needs basis and in the most optimal way possible.

Beside adequate crude fibre and feed structure supply, energy and further nutrients, sufficient nitrogen is the most important prerequisite for a high protein synthesis in ruminants. A balanced N supply reduces the risk of energy shortfalls and positively affects the cow's

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Fig. 1. Interpretation of nitrogen use efficiency (NUE) values (adapted from Chase, 2007).

NUE (%)		
>35	Best scenario	Ensure CP is not deficient
30-35	Very good	Minor adjustments needed to increase NUE
25-30	Good	Opportunities for improvement
20-25	Low	Make changes to the ration
<20	Very low	Excretion levels of N are high and N efficiency is low

<table>
<tr><th>Stage of lactation</th><th>‹9</th><th>9-11</th><th>12-14</th><th>›15</th></tr>
<tr><td>Early (0-30 days)</td><td>Lack of dietary protein</td><td rowspan="3">Most desirable</td><td rowspan="2">Acceptable</td><td rowspan="2">Excess dairy protein</td></tr>
<tr><td>Peak and post peak (31-150 days)</td><td rowspan="2">Intake and milk yield may be sub-optimal</td></tr>
<tr><td>Mid-late (‹150 days)</td><td colspan="2">Check RDP, RUP and/or adjust NFC</td></tr>
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Fig. 2. Guideline for interpreting whole herd MUN values (mg/dl, according to Hutjens & Chase, 2012).

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fertility, whereas an oversupply of N burdens the liver as the main metabolic organ and should therefore be avoided.

In addition, inefficient N use inevitably burdens the animal, the environment and also, of course, the economic efficiency.

The containment of ammonia emissions to the environment is a consistent challenge facing agriculture.

Besides many other aspects, feeding, especially protein supply, plays a crucial role. Protein efficiency describes the ability of a dairy cow to metabolise protein and non-protein N into milk protein.

Ruminal nitrogen balance

A protein surplus or deficiency situation in the rumen is expressed by the ruminal nitrogen balance (RNB). It is a benchmark for a sufficient supply of nitrogen to the rumen micro-organisms of dairy and rearing cattle. In order to fully exploit the microbial activity in the rumen and the performance potential of the animals, a zero balance (RNB=0) in the total ration is aimed for. Therefore, it is important to prevent a more than 10% nitrogen over- or undersupply.

Nitrogen use efficiency (NUE)

Animal nitrogen use efficiency [NUE = Milk nitrogen (kg/day)/Nitrogen in the diet] is defined as the percentage of total feed N intake incorporated into milk and meat. The NUE value is seen as a useful indicator in order to optimise feed use whilst minimising N losses, and ranges from below 20% to a theoretical maximum of 45% and is usually around 30%.

However, though the NUE is commonly used to evaluate the relative transformation of N inputs into animal derived products (for example, milk) and to point out the risk of N losses into the environment, it is always situation and impact dependent. This means that it is not advisable to think that a high NUE necessarily indicates low risks of N loss. Especially in highly intensive systems, the NUE can be high but at the same time the risk of N losses can still be significant.

However, high utilisation of N input, whilst keeping the risk of N losses at a minimum and at the same time not affecting productivity, should be targeted.

Consequently, for dairy farmers the challenge is to minimise the crude protein level in the diet, thus reducing feed costs and N losses in the environment, but without sacrificing milk production.

Certain feed additives, including phytogenics, can help to reach this target, as they are able to support animals' performance through enhancing nutrient efficiency and unfold their efficacy, where it is most effective: in the intestine of the livestock.

Ruminohepatic circle and milk urea nitrogen (MUN)

The ruminohepatic circle describes the circulation between the rumen and liver in ruminants, leading to better utilisation of feed N. In the rumen, NH_3 is produced via deamination of amino acids or non-protein compounds (for example, urea and amides). The ammonia may be used for microbial growth, providing that energy is available. The ammonia released in the proventriculus is directly absorbed, reaches the liver directly (via blood), where it is converted into urea and thus detoxified.

The urea formed in the liver returns to the rumen via the salivary glands and through direct back diffusion via the rumen wall, where it is split into ammonia (NH_3) and carbon dioxide (CO_2) with the help of a bacterial urease. This makes it available again for amino acid synthesis by the bacteria living in the rumen. Urea that is not recirculated is excreted via the kidneys. Though part of the urea is released via the milk.

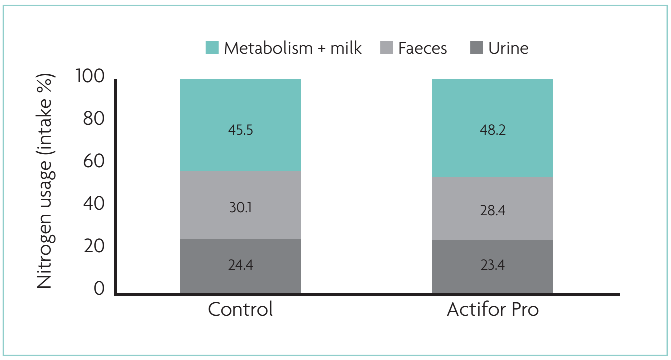
The milk urea nitrogen (MUN, 1mg MUN is equivalent to ~2mg of milk urea content) represents a helping tool to monitor the nutritional condition of the cow. As a waste product of the amino acid metabolism, it allows conclusions about the protein and energy supply of the animals and can be used to acquire a general estimate of the NUE of the herd.

Recommended MUN values range from 10-15mg/dl milk but recent research has reduced the advised range to 8-12mg/dl to reduce ammonia levels in the rumen, hence making interpretation challenging.

Typically, high MUN values indicate a low NUE and a high level of N losses in urine. Factors like feeding, breed (respectively body weight), or season seem to have an impact on the MUN.

Conclusions on the N efficiency can be drawn from the milk and blood urea N. The MUN may increase consequently to excessive protein or rumen degradable protein input. As the MUN is in close relationship to the urinary N excretion, it may be a helpful tool to reduce excessive N excretion. Providing adequate rumen available carbohydrates as energy source for the rumen microbes, making them convert ammonia into microbial protein seems to be a crucial target.

Fig. 3. Effect of Actifor Pro on protein efficiency.



Feed the rumen – with phytogenic feed additives

Do not feed the cow, but feed the bacteria in the rumen. The bacterial flora in the stomachs of ruminants is supported by the optimal composition of the feed.

A well-balanced amount of energy and protein supply is essential, if you want to use the rumen of dairy cows to its full potential.

Only an optimal microbial composition makes it possible to absorb nutrients from the ration in the best possible way. Milk production is strongly connected to the digestible protein supply available in the intestine. This once again shows the importance of high-quality microbial protein being washed from the rumen to the intestine.

Phytogenic (plant-based) feed additives (PFA) have been able to substantially up-value ruminant rations for years. Well-formulated formulations, aligned to the animal's needs, are able to support protein efficiency hence helping to keep protein losses low.

There is evidence that these natural, holistic solutions, made of, for example, essential oils, saponins, pungent substances and condensed tannins unfold their impact on three levels and in various sections of the digestive tract:

- In the rumen: improved rumen function leads to improved energy and protein efficiency ratio, increasing the proportion of metabolisable bypass protein and microbial protein (the latter shows a very good amino acid balancing to build up milk casein). Consequently, this will lead to lower ammonia losses from the rumen, via the liver (where it is transformed to urea) into the urine.
- A reduction of the protein degradation in the rumen will increase the level of bypass protein, and thus, lowering protein losses.
- The natural ingredients of selected PFAs positively influence the protein digestibility and absorption in the small intestine. By increasing the proportion of metabolisable bypass protein and microbial protein, the share of indigestible protein is minimised. This will reduce protein in faeces and lower ammonia concentrations.

The positive performance effects of a well-formulated phytogenic feed additive (Actifor Pro) are illustrated in Fig. 3.

Phytogenic substances have been shown to reduce both protein losses in urine and faeces. This means that the intestinal digestibility could be improved, and less ammonia transformed into urea.

The more efficient use of N for milk production, maintenance and growing led to an improved protein efficiency by 2.7%.

Optimising protein and feed efficiency in ruminants improves the milk quality by raising its protein content whilst simultaneously

	Control group	Actifor group	Actifor Pro Effect	P-value
DIM at beginning (days)	84.9	87.6		NS
Milk yield (kg/cow/day)	27.9	29.5	+1.6	0.04
Energy Corrected Milk (kg/cow/day)	30.5	33.0	+2.5	0.01
Fat corrected milk (kg/cow/day)	30.0	32.6	+2.6	0.02
Milk fat [TB] (%)	4.01	4.10	+0.09	NS
Milk protein [TP] (%)	3.35	3.34	+0.01	NS
Lactose (%)	4.59	4.66	+0.07	NS
MUN (mg/dL)	13.5	13.3	-0.02	NS
SCC (log/mL)	5.11	5.02	-0.09	NS
BCS change	+0.07	+0.22	+0.15	0.05
Energy output (Mcal/day)	20.5	22.3	+1.8	0.01

Table 1. Effects of Actifor Pro on dairy cows performance (according to Rodrigues et al., 2019; DIM = days in milk, MUN = milk urea nitrogen, SCC = somatic cell count, BCS = body condition score).

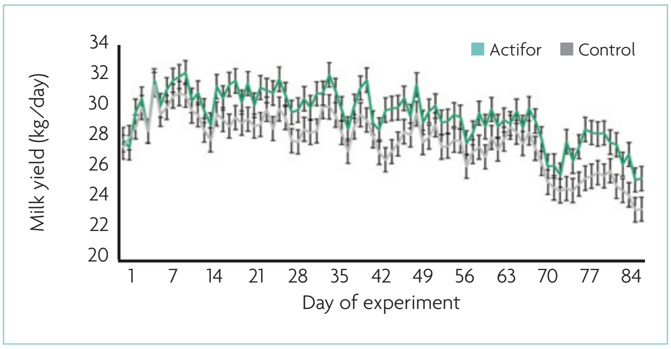


Fig. 4. Effects of Actifor Pro on milk yield in dairy cows (Rodrigues et al., 2019).

decreasing urea concentration. MUN was decreased from 261mg/l in control animals to 219mg/l in cows fed the PFA (data not shown).

Another study using Actifor Pro was undertaken in Brazil, to look at the potential to improve performance in dairy cows over a period of 12 weeks (see Table 1 and Fig. 4). The inclusion of the phytogenic feed additive mainly increased milk production (+ 1.6kg/cow/day) and the energy corrected milk production (+ 2.5kg/cow/day). At the same time, body condition score was increased by 0.15. Supplementing lactating dairy cows with well selected phytogenic feed additives like Actifor Pro appears to be a promising strategy to improve milk performance, whilst at the same time reduce protein losses in dairy production systems.

Possible reduction of crude protein level in diets due to in-feed phytogenics will consequently lead to decreased feed costs as well.

Conclusions

In dairy milk production attention is mostly concentrated on efficiency. Therefore, maintaining very high-quality rations, hence making it possible to fully exploit the genetic potential of the dairy cows, plays an important role in optimal management.

There is evidence that optimising rations with phytogenic feed additives represents reliable, cost effective ways, ensuring feed and protein efficiency respectively.

This not only leads to improved animal performance but also contributes to cost-efficient milk production, animal well-being and environmental protection. ■

References are available from the author on request