Ketosis in dairy cows and the role of choline

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During the start of a lactation dairy cows enter a stage of negative energy balance. The reason behind this is that energy output for milk production is higher than the energy intake from the consumed feed. Body reserves in the form of fat will be mobilised and this may lead to fatty liver and (subclinical) ketosis. Choline is known for its positive effects in such a case. This article looks at the exact role of choline and in what form choline should be supplied.

Ketosis and choline

Ketosis is a metabolic disorder that is characterised by elevated concentrations of ketone bodies in blood, urine and milk. The disease mainly occurs in early lactation when body reserves are used to support lactation. The disorder can have a clinical and a subclinical presentation.

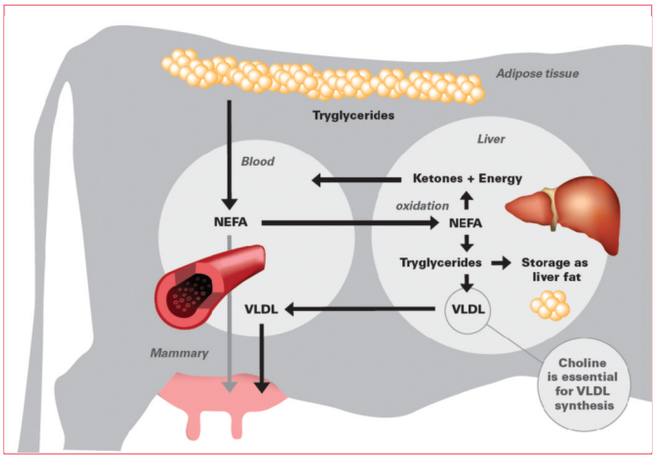
Clinical ketosis occurs less frequently than subclinical ketosis and affects individual animals in a herd; cows show a decrease in feed intake, weight loss, a drop in milk yield, acetone smell of breath, depression, and occasionally nervous signs.

Researcher	Year	Country	Subclinical ketosis		Size of study	
			Prevalence (%)	Range (%)	No. cows	No. herds
Duffield	1998	Canada	32.0		507	25
Schmitt	2007	Brazil	19.0		500	
Corbellini	2011	Argentina	18.2		3867	9
McArt	2012	USA	43.0	26-56	1717	4
Suthar	2012	EU (10 countries)	21.8	11-37	5884	528
Compton	2013	New Zealand	14.3	0–60	1620	57

Table 1. Overview of studies on prevalence of subclinical ketosis.

Subclinical ketosis is often herd related and is associated with lower milk yield, elevated milk fat content (relative to protein content), reduced reproductive performance and an increased risk of removal from the herd. Animals with subclinical ketosis also have higher risks for clinical ketosis and displaced abomasum.

Fig. 1. Lipid metabolism in the dairy cow and the role of choline.



Ketosis is related to fat mobilisation. In early lactation dairy cows are exposed to an increased mobilisation of body fat reserves. Body fat is also called adipose tissue and the fat in this tissue is present in the form of triglycerides (glycerol with three fatty acids).

These triglycerides are released from the adipose tissue into the blood in the form of free fatty acids (also called non-esterified fatty acids, NEFAs).

These NEFAs reach the liver and there they can be either oxidised for energy (resulting in higher levels of ketones) or removed again out of the liver in the form of VLDL (very low density lipoproteins).

The rate of fat absorption by the liver can be higher than the rate of oxidation and the transport out of the liver. This may lead to an accumulation of fat in the liver, resulting in fatty liver syndrome.

Choline is a component of phosphatidylcholine, which is necessary for synthesis of VLDL, the lipoprotein that is responsible for the transport of fatty acids out of the liver.

Choline is essential for the synthesis of VLDL and therefor plays a crucial role in fat metabolism. Fig. 1 shows these pathways of the fat metabolism in the dairy cow.

Incidence and cost

The incidence of ketosis has been evaluated in several studies in different parts of the world.

In a recent study in New Zealand it was concluded that prevalence of subclinical ketosis was 14.3% on average, but cases of up to 60% were reported. In a large survey over 10 European countries, it has been shown that the incidence of subclinical ketosis was 21.8% on average, ranging from 11.2% to 36.6%. South American studies showed a prevalence of 19% and in USA average prevalence of 43% was reported with cases up to 56%.

Table 1 shows an overview of studies on the prevalence of subclinical ketosis. Ketosis can lead to high costs in dairy production.

The cost of ketosis are associated with a lower milk yield and an increased risk of a wide range of diseases. The direct costs include the

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veterinarian's and the herdsman time, drugs, discarded milk, reduced yield and other costs. The indirect costs include increased risk of other diseases, extended calving intervals, higher culling rates, extra services per conception and the increased risk of fatality.

For each affected cow the total costs of subclinical ketosis have been calculated to be $955 (€735). On a farm with a prevalence of subclinical ketosis between 20-30% this represents a cost between $190-286 per average cow in the herd. For a farm with 100 dairy cows the total costs can add up to $29,000 per year.

	Control	Choline	Difference
Milk yield (kg/day)			
day 0-30	37.34	37.43	0.09
day 31-60	42.2	42.57	0.37
day 61-90	39.03	39.59	0.56
Fat (%)			
day 0-30	4.96	4.58	-0.38
day 31-60	4.01	3.92	-0.09
day 61-90	3.88	3.84	-0.04
% of cows with elevated fat % (fat-protein>1.25)			
day 0-30	50	35.3	-30%
day 31-60	35.3	19.4	-46%

Table 2. Milk yield (kg/day), fat % and % of cows with elevated fat % (fat-protein>1.25).

Intestinal availability

Choline is considered a non-essential nutrient for ruminants, meaning that the dairy cow can produce it by herself. However there are indications that the quantity is limited and consequently adding extra choline to the ration is a good strategy to optimise health.

Supplemented choline needs to be available on an intestinal level. Unprotected choline will be broken down in the rumen and will lose its effects. To overcome degradation in the rumen, several rumen protected products are available.

Rumen protection or rumen bypass means that the choline is covered by a protective layer. This is mostly a layer of a fatty acid matrix, which restrain the rumen microbes from utilising the choline. The protective layer must be broken down later on in the digestive tract at the site of the small intestine. Here, the digestive enzymes break down the fatty layer and the choline is free for absorption.

Rumen bypass as such does not necessarily mean the product is effective. Some products are over protected. The protection can be so strong that the choline is not released in the intestine at all. Other products are under protected, which means that the protection layer is not able to provide sufficient rumen survival. This leads to the choline being partially or even completely degraded in the rumen before it even reaches the intestine.

Combined in vitro/in vivo trial work demonstrates this 'overprotection' and 'under protection' of some products. In this test the rumen protection is measured with a so called 'In Sacco method' and a Daisy incubator. Samples of the product are introduced into the incubator and after 12 hours how much choline remains is measured (means rumen stable).

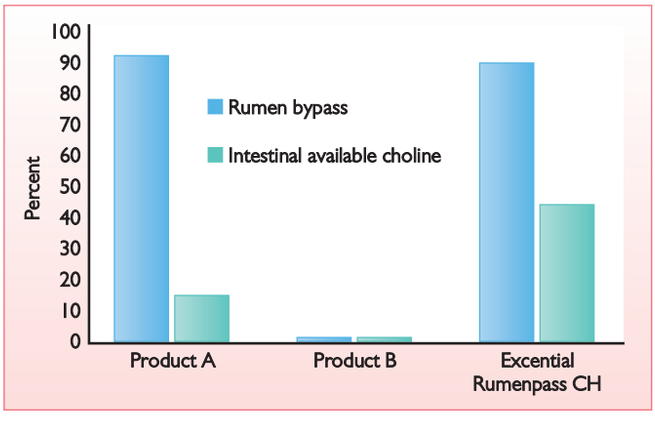
Next the products are entered into the small intestine of a duodenum-cannulated dairy cow and collected in the faeces.

This so called 'mobile nylon bag method' is a well accepted method to determine the intestinal digestibility of products. The amount of choline that is eventually available for the animal is the result of the rumen stability times the intestinal digestibility. The results for rumen stability as well as for the intestinal available choline are shown in Fig. 2.

As can be concluded from this graph, there are big differences between products in the market. Product A has a very strong rumen protection, but this protection is so strong that very little is available in the intestine (overprotected).

Product B has a very low rumen protection (under protected), therefore choline never even reaches the intestines. The key to developing rumen protected products is to find the right balance between rumen protection and intestinal digestibility. Orffa and Excentials have developed their product Excential Rumenpass CH. This product has a very effective rumen protection and a very high intestinal digestibility, which results in the highest amount of choline available for the dairy cow.

Fig. 2. Rumen bypass and intestinal availability of different products on the market



Practical trial results

Trial results show that the use of protected choline is a preventive measure for avoidance of fatty liver syndrome and ketosis around calving and may improve milk production and reproduction parameters.

To evaluate the effect of supplementation of rumen protected choline under practical conditions, a trial was performed on a Dutch dairy farm with approximately 250 cows. Lactating cows were housed in four different groups – heifer group, fresh cow group and two groups with multiparous cows. Milking was done by an automatic milking system (one milking robot per group).

During a five month period all fresh (multiparous) cows were assigned directly after calving to the control or the treatment group (receiving Excential Rumenpass CH at a dosage of 60g/cow/day). After calving the animals were followed up to 90 days in milk.

One week after calving, urine samples were taken and analysed for ketones and given a value from 0 (no ketones) to 6 (extreme level of ketones).

The average score for the treatment group was 15% lower compared to the control group. The periodic milk sampling showed that cows receiving the choline had a numerically higher daily milk production. The fat percentage in the milk was significantly lower. There was no difference in protein percentage. The results for milk yield and fat percentage are shown in Table 2.

The lower fat percentage is seen as a positive sign, since an elevated fat content with a normal protein level is related to ketosis.

A difference between fat percentage and protein percentage of more than 1.25 is considered as a high risk for subclinical ketosis.

In this trial it was shown that in the control group 50% of the cows showed this elevated fat % in the period from 0-30 days.

In the period from 31-60 days this was 35%. In the treatment group with rumen protected choline the percentage of cows with elevated fat% (sign of subclinical ketosis) was reduced by 30% and 46% in the period from 0-30 days and 31-60 days respectively (Table 2).

These positive results have been confirmed in a follow up trial on another Dutch dairy farm. On this farm with approximately 90 dairy cows all cows were supplemented with rumen protected choline (Excential Rumenpass CH) for a period of four weeks. The results were compared with historical data from that farm.

	Before treatment	After 4 weeks supplementation with choline
Percentage of cows with elevated fat % (fat-protein>1.25)	61	32
No. of cows with elevated ketones in milk	4	1

Table 3. Percentage of cows with elevated fat % (fat-protein>1.25%) and number of cows with elevated ketones in milk.

After four weeks of supplementation the amount of cows 'at risk', meaning cows with an elevated fat%, was almost reduced by half. Also the number of cows that had detection of ketones in the milk was strongly reduced (Table 3).

Conclusion

Subclinical ketosis is a metabolic disorder which has a great impact in dairy production. Studies worldwide show that the incidence is between 20-30% and the costs related to subclinical ketosis are very high.

Nutrition is a key in preventing subclinical ketosis and specifically choline has an important role.

Supplementation of choline in a rumen protected and intestinal available form can be a practical tool for a dairy farmer as part of a total nutritional strategy to lower subclinical ketosis. ■

Excential Rumenpass CH

Rumen bypass choline

Effective rumen protection, high intestinal availability

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