Aus dem Institut für Tierernährung

Kirsten Stemme
Peter Lebzien
Henner Scholz
Ulrich Meyer
Gerhard Flachowsky

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Manuskript, zu finden in www.fal.de

Published in: Vitamine und Zusatzstoffe in der Ernährung von Mensch und Tier : 9. Symposium 24. und 25. September 2003 Jena/Thüringen, pp. 61-68

Braunschweig
Bundesforschungsanstalt für Landwirtschaft (FAL)
2003

Cobalt and vitamin B_{12} requirement of dairy cows

Stemme, K.[1], Meyer, U.[2], Lebzien, P.[2], Flachowsky, G.[2], Scholz, H.[3]
[1] Institute of Animal Nutrition, School of Veterinary Medicine, Bischofsholer Damm 15, 30173 Hannover
[2] Institute of Animal Nutrition, Federal Agricultural Research Centre, Bundesallee 50, 38116 Braunschweig
[3] Clinic for Cattle Diseases, School of Veterinary Medicine, Bischofsholer Damm 15, 30173 Hannover

Vitamin B_{12} (also called cobalamin) is unique among the vitamins in that it contains an essential mineral (cobalt) as the central atom and that it is synthesised only by some bacteria, blue-green algae and yeast. Therefore it is not present in feedstuff of plant origin. Because of some micro-organisms in their forestomachs (8 strains of cobalamin producing bacteria; Dryden et al. 1962) ruminants are able to synthesise Vitamin B_{12}. So ruminants do not need a ration containing vitamin B_{12}, but cobalt. The cobalt requirement of ruminants is actually a cobalt requirement of the rumen micro-organisms, which incorporate it into vitamin B_{12} (McDowell 2003). But the ruminant makes extremely inefficient use of its dietary cobalt. The production of cobalamin from cobalt accounted only for about 3 - 15 % in sheep (Smith and Marston 1970) and 7.5 - 11 % in dairy cows (Stemme 2002). Higher cobalt intake usually leads to a higher cobalamin synthesis, as shown in Table 1.

Table 1: Vitamin B_{12} synthesis (mg/day and mg/kg DM intake) in relation to the Co supply of adult ruminants

animals	Co-intake (mg Co/kg DM)	vitamin B_{12} synthesis mg/animal and day	mg/kg DM intake	authors
sheep	0.01 - 0.05 1.0	0.05 - 0.11 0.4 - 0.7	no data no data	Smith and Marston (1970)
sheep	0.047 0.41 0.83	0.037 1.0 1.5	0.07 1.72 2.69	Hedrich et al. (1973)
sheep	0.01 - 0.05	no data	0.33 - 1.8	Bigger et al. (1976)
cattle	no data	9,2 - 10,6	2,2	Zinn et al. (1987)
dairy cows	0.17 0.29	2.51 - 4.19 6.00 - 11.29	0.19 - 0.31 0.44 - 0.84	Stemme (2002)

Beside the cobalt content in the ration there are other influences on the microbial vitamin B_{12} synthesis in the rumen. Increasing the roughage content in the ration and the dry matter intake increases the cobalamin production in the rumen (Smith and Marston 1970; Walker and Elliot 1972; Hedrich et al. 1973), while high concentrate contents in the ration lead to a reduced vitamin B_{12} synthesis.

In contrast to humans there is only little known about cobalamin absorption in ruminants. It is suggested, that it is the same mechanism as described in humans (Seetharam and Alpers 1982), but cobalamin seems to be less completely absorbed in ruminants than in monogastric species. In the literature there are different information concerning the efficiency of cobalamin absorption in the ruminant (1 - 48 % of the produced vitamin B_{12}; Table 2).

Table 2: Vitamin B_{12} absorption in ruminants

absorption (%)	Co supply	authors
5	1 mg/sheep and day	Smith and Marston (1970)
1-3	no data	Girard (1998)
3-38	no data	Gruner (2001)
8-38	0.12 - 1.31 mg/kg DM	Rickard and Elliot (1978)
up to 20	0.06 – 1.02 mg /kg DM	Hedrich et al. (1973)
48	no data	Zinn et al. (1987)

Although there are at least 10 different biochemical reactions known, which require cobalamin, only two enzyme systems (methionin synthase, methyl malonyl CoA mutase) are known in mammalians (Zagalak 1982; Gruner 2001). In ruminants the most important one is the methyl malonyl CoA mutase, which is involved in the transformation of methylmalonyl-CoA into succinyl-CoA. This reaction is particular important for ruminants because of its involvement in the metabolism of propionic acid, the most important source of energy for ruminants (Gruner et al. 1998). The other enzyme is an essential part in the transformation of homocystein into methionin, which is part of the regeneration process of folic acid.

Cobalt deficiency is reported from several regions all over the world (Australia: Marston 1935; New Zealand: McNaught 1948 ; USA: Ammermann 1969; tropical regions: McDowell et al. 1993). Animals show unspecific clinical symptoms such as an reduced feed intake, retarded growth, muscular wasting, a rough hair coat and thickening of the skin. Often reproductive disorders and reduced milk yield are seen in the case of vitamin B_{12} deficiency.

Cobalt requirement of ruminants

The present cobalt recommendations for dairy cows (Table 3) are based on experiments which were carried out mainly with sheep (Smith and Marston 1970; Hedrich et al. 1973; Bigger et al. 1976) and beef cattle (Stangl et al. 2000 a and b; Schwarz et al. 2000).

Table 3: Recommended allowances of cobalt for dairy cows (mg/kg DM)

INRA (1988)	ARC (1989)	GfE (2001)	NRC (2001)
0.11	0.11	0.20	0.10

To answer the question, whether these recommendations are adequate for dairy cows, investigations on the cobalt supply of dairy cows were done, in which the influence of a higher cobalt supply on the feed intake, the milk yield and milk composition as well as on the vitamin B_{12} status of the cows and their calves was examined. The feeding trial was divided into two periods. In the first period lasting 112 days 54 cows (German Holsteins; 1.-6. lactation) were fed rations with different cobalt contents (0.13, 0.20 and 0.27 mg Co/kg DM). After this time the trial was continued with 10 cows each from the first and third group (0.13 and 0.27 mg Co/kg DM) until calving. The results can be summarised as follows:

- *feed intake*

In contrast to Schwarz et al. (2000) who detected a higher dry matter intake in cattle, in the investigations with dairy cows a higher cobalt content in the ration did not result in a higher dry matter intake.

- *milk yield and milk composition*

In the period under study cobalt supplements did not significantly affect milk performance. The average FCM yield, calculated over the first 112 experimental days, amounted to 29.0 ± 5.2 kg for controls and 29.7 ± 5.7 kg or 28.7 ± 4.4 kg for the experimental groups (II and III), respectively. The same relations were found for the second part of the feeding trial. Fat, protein and lactose concentrations in the milk were also not influenced by cobalt supplementation (Table 4).

Table 4: Milk yield and milk composition in relation to different cobalt levels in the ration

	group I	group II	group III
Number of animals	18	18	18
Co content (mg Co/kg DM)	0.13	0.20	0.27
milk yield (kg FCM/Tag)	29.0 ± 5.2	29.7 ± 5.7	28.7 ± 4.4
milk fat (%)	4.19 ± 0.43	4.43 ± 0.47	4.41 ± 0.44
milk protein (%)	3.33 ± 0.26	3.41 ± 0.28	3.39 ± 0.20
lactose (%)	4.96 ± 0.13	5.02 ± 0.11	4.97 ± 0.14

- *Vitamin B_{12} status*

The comparison of the measured vitamin B_{12} concentrations in the blood serum of all cows used in the experiment with data from the literature (Scholz 1990; Puls 1994) leads to the conclusion, that the cobalt supply was sufficient. According to the results from Girard and Matte (1999) an increase of the vitamin B_{12} concentration was detected in the course of lactation for all dietary cobalt levels (Table 5).

Table 5: Vitamin B_{12} concentration (pg/ml) in the serum of dairy cows in relation to the cobalt supply

exp. day	0	28	56	84	112	140	168	196	224	252	calving
group I[1)]	180 ± 40	194 ± 30	176 ± 23	180 ± 28	213 ± 22	214 ± 28	205 ± 40	231 ± 27	227 ± 39	216 ± 42	276 ± 43
group III[2)]	155 ± 21	193 ± 18	176 ± 23	181 ± 30	208 ± 20	194 ± 27	218 ± 55	209 ± 32	241 ±43	246 ± 51	315 ± 91

1) Co- supply: group **I** = 0.13 mg Co/kg DM; group **III** = 0.27 mg Co/kg DM

Reports from literature, which say that a higher Co supply results in significantly higher Vitamin B_{12} concentrations in the serum (Marston 1970; Jones and Anthony 1970) could not be confirmed, but in those reports the Co supply was much lower than in the own experiments.

Independent of the cobalt supply the cobalt and vitamin B_{12} concentration in the liver tissue decreased in the course of lactation. However, the experimental group showed a tendency towards higher values on experimental days 100 and 200 due to a higher cobalt supply. On the day of calving this difference proved to be significant (Table 6).

Cobalamin concentration in the liver tissue of clinically normal cattle ranged from 0.58 to 2.70 mg/kg wet weight (WW; Rammell and Poole 1974). Although vitamin B_{12} concentrations in the liver tissue of the cows in the own experiments ranged between 0.64 - 0.75 mg/kg WW in the experimental group and 0.51 - 0.64 mg/kg WW in controls, it can be concluded, that the cobalt supply of the cows in the own experiment was sufficient in both groups.

Table 6: Vitamin B_{12} concentration in the liver tissue (mg/kg WW) of dairy cows in relation to the cobalt supply

	day 100	day 200	day of calving
group I (0.13 mg Co/kg DM)	$0.64^{Aa} \pm 0.07$	$0.61^{Aba} \pm 0.09$	$0.51^{Bb} \pm 0.06$
group III (0.27 mg Co/kg DM)	$0.75^{Aa} \pm 0.04$	$0.70^{Aa} \pm 0.05$	$0.64^{Aa} \pm 0.06$

a,b: means within lines with different superscripts are significantly different ($p<0.05$)
A,B: means within columns with different superscripts are significantly different ($p<0.05$)

Dietary cobalt levels did not affect vitamin B_{12} concentration in milk. Only a marginal increase was detected in the course of lactation (Table 7). Vitamin B_{12} concentrations in the colostrum were detected to be 4 to 6 times higher compared to milk. Colostrum showed a tendency towards a higher Vitamin B_{12} concentration due to cobalt supplementation, but results failed to be significant (Table 7).

Table 7: Vitamin B_{12} concentration (ng/ml) in milk and colostrum of dairy cows in relation to the cobalt supply

	milk		colostrum
	exp. day 0	exp. day 220	exp. day 280
group I	3.77 ± 1.41	4.75 ± 3.05	16.7 ± 11.6
group III	3.66 ± 1.03	4.44 ± 0.96	21.0 ± 8.39

1) Co-supply: group I = 0.13 mg Co/kg DM; group III = 0.27 mg Co/kg DM

Extra cobalt supplementation to the ration of pregnant cows did not result in increased vitamin B_{12} concentrations in the serum of their calves before they received colostrum. After the intake of colostrum the cobalamin concentration in the serum of the calves increased in both groups and decreased afterwards (Table 8).

Table 8: Vitamin B_{12} concentration (pg/ml) in the serum of the calves in relation to the cobalt supply of the cows[1)]

	day of birth*	1st day of life	2nd day of life	5th. day of life
group I	320 ± 67	342 ± 162	206 ± 56	185 ± 40
group III	319 ± 123	361 ± 186	211 ± 36	187 ± 30

1) Co-supply: group I = 0.13 mg Co/kg DM; group III = 0.27 mg Co/kg DM
* prior to colostrum intake

Conclusion: From the results it can be concluded that a cobalt supply of 0.13 mg/kg seems to be sufficient to cover the requirement of lactating dairy cows fed a ration based on wilted grass silage. This value is lower than the present recommendation of the GfE (2001). In Germany the cobalt content in roughage is usually high enough to cover the requirement (Table 9). Feeding dairy concentrate containing mineral supplements cover the requirement even in regions with lower Co content in the roughage.

Table 9: Average cobalt content in roughage in several regions of Germany

	LUFA Bonn (2000 – 2002)	LWK Schleswig-Holstein (1990/1995)	WEISS und JANSSEN (1992) Hessen	STEMME (2002) Braunschweig
grass silage	n=32 **0.50** <0.10 – 3.58	n=20 **0.07** 0.01- 0.2	n=11 **0.39** 0.14 – 0.96	n=7 **0.13** 0.04 – 0.31
maize silage	n=9 **0.11** <0.10 – 0.18	n=5 **0.02** -	n=8 **0.06** 0.03 – 0.13	n=1 **0.18** -
whole crop silage	n=3 **0.14** <0.10 – 0.22	n=5 **0.02** -	**-**	-

Summary: Cobalt (Co) is known to be an essential component in microbial synthesis of vitamin B_{12} (also called cobalamin) in ruminants, as it is the central atom of the vitamin B_{12} molecule. As cobalamin is not present in feedstuffs of plant origin, the vitamin B_{12} supply of ruminants has to be ensured by a sufficient Co supply.
In mammalian metabolism vitamin B_{12} is an essential part of enzyme systems. In ruminants the most important one is the methyl malonyl CoA mutase, which is involved in the metabolism of propionic acid, the most important energy source for ruminants. Co deficient animals show unspecific symptoms such as poor appetite, reduced performance and reproductive disorders.
It has been reported that roughage contains in many areas of the world less than 0.1 mg Co/kg DM which is not enough to meet the requirement of ruminants. In Germany the Co content of roughage – with the exception of a few regional differences – is high enough to meet the estimated requirement of lactating dairy cows (0.13 mg Co/kg DM). Feeding a mineral supplement, which has to contain at least 10 mg Co/kg (German feed legislation), usually covers ruminants' requirement even in regions of Germany with lower Co contents in roughage.

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Newer aspects of vitamin and trace element nutrition in turkeys
Neuere Aspekte zur Vitamin- und Spurenelementversorgung von Puten

Schenkel, H.
Landesanstalt für Landwirtschaftliche Chemie, Universität Hohenheim, Emil-Wolff-Str. 14, 70599 Stuttgart

Newer aspects of vitamin nutrition of turkeys were among others focussed on the effect of vitamin supply of the eggs on the viability of embryos and poults. For some vitamins like vitamin E turkey poults showed differences in metabolism compared to other poultry species. The improvement of oxidative stability of body fat by vitamin E supplementation before slaughtering was a topic of a series of publications during the last years. Bone mineralization and bone stability and nutrition (vitamin D active compounds, minerals and trace elements) is still under discussion. Among water soluble vitamins, biotin supplementation in connection with foot pad lesions was discussed intensively. Also effect of vitamin supplementation on infectious diseases was of interest. Finally values for vitamin supplementation disussed by the GfE were presented in this short review.

Trace element supplementation of turkey diets is under discussion for several aspects: supplementation after avoidance of feedstuffs of animal origin and the use of high phytate containing ingredients, special effects of organic bound elements, environmental pollution, discrepancies between recommendations of breeders and scientific organisations.
Several elements like zinc and selenium were reviewed with respects to there interactions with vitamins and their effects on immunological reactions.
The proposals of the new EU-directive for trace element supplementation implaied no serious effects on optimal element supply of turkeys. Proposals for recommendations discussed by GfE are presented.