B Vitamins for Ruminants

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INTRODUCTION

The lack of sufficient quantities of B vitamins can contribute to reduced productive performance in livestock and poultry. Symptoms of marginal B vitamin deficiencies in monogastric species include low appetite, reduced reproductive performance, poor feed efficiency and lowered immune response. Ongoing issues in dairy cattle include reduced intake, lower levels of milk components, low pregnancy rate, metabolic complications, and hoof problems. In beef cattle reduced immune response and poor feed efficiency are common complaints. The similarities between the symptoms of marginal B vitamin insufficiencies in monogastrics, and unresolved issues in ruminants are quite striking.

B vitamins are obligatory for the regulation of metabolic processes in all mammalian species, including ruminants. The functions of these compounds are wide ranging and impact all aspects of health and productivity. This article will provide a brief overview of the information available regarding B vitamins and demonstrate that ruminants do, in some situations, benefit from the inclusion of water-soluble vitamins in their diets.

B VITAMINS FOR RUMINANTS

B vitamins have been reasonably well studied in swine and poultry, but less so in ruminants. Vitamin nutrition was topical in the 1940s and 1950s, when many vitamins were being discovered and assay methods for them were being developed. In 1950, milk production in the United States averaged 5,300lbs./cow/year (Blayney, 2002). Feedlots were just being conceptualized (Hubbs, 2010) and most beef was produced from slow-growing cattle on grass. Thus, researchers in those early years correctly showed- based on the productive capacity of the animals they studied- rumen microbes were capable of producing sufficient quantities of B vitamins to supply host animals with the B vitamins they needed. That notion was ingrained into the next several generations of ruminant nutritionists, even as productivity of both beef and dairy cattle accelerated.

The 8th Revised Edition of Nutrient Requirements of Beef Cattle was not available at the time of writing this review. The 7th edition (NRC, 2000) mentioned as noteworthy research regarding vitamin B12, choline, niacin and thiamin, but noted that the vitamins are largely degraded in the rumen, and supplementation is of practical consequence only in animals prior to rumen development. The 8th Edition of Nutrient Requirements of Dairy Cattle is under construction. The current version (NRC, 2001) advanced the subject of B vitamin nutrition by providing estimations of net requirements for B vitamins for maintenance and milk production. No estimates of bioavailability of the vitamins were provided, and the publication noted that usage for health and gestation could not be estimated with the information available to the committee. New information has come to light since the two NRC publications, and awareness is developing regarding the need for B vitamins for ruminants.

BIOAVAILABILITY

In order to meet net requirements for B vitamins, bioavailability must be estimated. Bioavailability in monogastrics animals has been shown to vary with the source of the vitamin as well as the intended

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species. Using biotin as an example, Zempleni and Mock (1999) determined that synthetic biotin was 100% bioavailable in adult humans. In contrast, biotin from cereals ranged from 24-33% bioavailable for swine (Misir and Blair, 1988b) but only 16-30% for turkeys (Misir and Blair, 1988a). Availability from soybean meal and canola meal were similar at about 70% for both species. Thus, information on source of each vitamin as well as target species is key to providing an adequate supply of these nutrients.

With ruminants, availability for ingredients is further modified by rumen microbes. As Table 1 shows, most of the vitamins originating from ingredient and supplemental sources are degraded in the rumen, such that the host animals must rely almost entirely on vitamins synthesized by rumen microbes. This suggests that bioavailability from microbial cells should be assessed for ruminants.

Table 1. Rumen degradation of B vitamins

	Reference	
Extent of Degradation, %	**NRC, 2001**	**Santschi et al., 2005**
Biotin	0	45
Folic acid	97	97
Niacin	94	0*
Pantothenic acid	78	Not evaluated
Riboflavin	99	99
Thiamin	48	68
Vitamin B6	100	41
Vitamin B12	90	63

* Nicotinamide was determined to be absorbed before reaching the duodenum, giving the appearance of total degradation

In two separate feeding trials, Santschi et al. (2005) evaluated the absorption of B vitamins from duodenal contents in control animals receiving no supplemental B vitamins and from animals post-ruminally infused with B vitamins (Table 2). Because such high proportions of B vitamins are destroyed in the rumen, the vitamins appearing in the duodenum would be expected to be of microbial origin as represented by the control values in Table 2. The absorption of the infused vitamins is indicated by the treatment in which vitamins were supplemented.

Table 2. Calculated bioavailability of post-ruminal B vitamins

	Treatment	
Absorption, % of total	**Control**	**Supplemented**
Biotin	28-46	36-37
Folic acid	<1	10-16
Niacin	84	84-85
Pantothenic acid	Not evaluated	Not evaluated
Riboflavin	35-37	36-37
Thiamin	73-77	55-67
Vitamin B6	89-90	73-85
Vitamin B12	11	15-16

The extent of absorption was found to be quite low for some of the vitamins no matter the source, notably folic acid and vitamin B 12. Less than half of the biotin and riboflavin supplied at the duodenum was absorbed. These values indicate that net requirements need to be adjusted quite considerably for some of these nutrients to meet metabolic needs.

MICROBIAL B VITAMIN PRODUCTION

One method of evaluating the amounts of B vitamins produced in the rumen would be to measure the amounts found in bacterial cells. Santschi et al. (2004) analyzed the vitamin composition of particle and liquid associated bacteria from cows receiving high and low forage diets. There were very few differences in vitamin concentrations of rumen microbes that could be associated with diet. Indeed, values were more similar than different between the solid and liquid associated bacteria, and for all practical purposes, the values can be averaged (Table 3). With the ability of existing feed formulation software to compute rumen microbial (bacterial) yield from diet formulations, the same metric could be applied to compute vitamin production, using this or other information on the vitamin composition of rumen microbes.

Table 3. Average vitamin content of rumen bacteria*

Vitamin, mg/kg bacterial DM	Amount
Biotin	11.4
Folic acid	2.2
Niacin	249.5
Pantothenic acid	Not evaluated
Riboflavin	43.9
Thiamin	15.0
Vitamin B6	26.2
Vitamin B12	20.7

* Santschi et al., 2014

Schwab and Shaver (2005) determined that the correlation between apparent vitamin synthesis and microbial N yield was low for most of the B vitamins. However, apparent synthesis is the difference between intake and gut appearance, with intake being diet dependent. If most of the test vitamins added directly to the diet are destroyed by rumen microbes, then apparent synthesis, as a difference value only, would change with intake, rather than production.

Estimations of microbial production were calculated by NRC (2001) based on digestible organic matter consumption. Many models compute microbial yield from rumen digested organic matter, and so rumen digested organic matter might logically be a reflection of microbial yield.

Estimates of rumen B vitamin synthesis as calculated by NRC (2001) are provided in the second column of Table 4 for a typical dairy cow producing 35 kg of milk. For discussion purposes, these values can be compared to estimations of requirements, after correcting for bioavailability.

NEEDS ABOVE MICROBIAL SUPPLY

Table 4 provides estimations of vitamin requirements in excess of microbial supply based on the method proposed by NRC (2001). Requirements estimations are minimums, and are limited to maintenance and milk, and do not include losses due to high water turnover, stress, gestation, etc. In addition, rumen synthesis values may or may not be calculated correctly due to the limited information available when the publication was written.

NRC predictions of rumen synthesis were adjusted based on bioavailability, and compared to net requirements. The calculations while crude, strongly suggest B vitamins needs are not being met by microbial supply alone.

Table 4. Estimations of Vitamin needs for a dairy cow producing 35 kg of milk per day (NRC, 2001) as compared to estimated rumen production

	Item			
Vitamin, mg/day	**Rumen Synthesis**	**Net Requirement**	**Bioavailable supply***	**Needs above microbial supply**
Biotin	14	6	7	0
Folic acid	7	35	1	34
Niacin	1804	289	1515	0
Pantothenic acid	38	425	38	387
Riboflavin	261	156	97	59
Thiamin	143	41	110	0
Vitamin B6	96	48	87	0
Vitamin B12	70	0.6	8	0

* Highest bioavailability value from control treatments provided in Table 2.

More research is needed to determine net and metabolizable B vitamin requirements. With a few exceptions, the effects of environment, stress, and gestation have not been evaluated for ruminants. An additional factor that needs consideration is the composition of growth in the case of beef cattle, and the composition of milk in the case of dairy cow. For example, in studies involving low and high protein genotypes of swine, Lutz and Stahly (1999) determined that the riboflavin required for each Mcal of energy used for body fat accretion was 3 times higher than maintenance, and the riboflavin required for each Mcal of energy use for protein accretion was 6 times higher than that required for fat. The same group of researchers showed that the provision of adequate amounts of B vitamins resulted in shifts towards greater protein growth (Lutz et al., 2004). Requirements may be quite different depending upon the composition of weight gain for beef cattle, and the composition of milk for dairy cows. B Vitamins may therefore offer opportunities to improve production and product composition.

RUMEN PROTECTED B VITAMINS

Several studies have been conducted evaluating the inclusion of single B vitamins on production in ruminants. Bonomi et al. (1998) determined that 40 mg of rumen protected vitamin B6 and reduced days to conception in dairy cows in their first 6 months of lactation. In comparison, at least 100 mg of unprotected vitamin B6 was required to achieve similar results. Interestingly calculations provided in Table 4 indicated that microbial production of this vitamin exceeds requirements. In another study (Bonomi et al., 2000) determined that 6 mg/day of folic acid improved reproductive performance.

Rumen protected niacin has been the subject of several studies in dairy. Recently, Yuan et al. (2011) found no benefit to supplying niacin during lactation in summer months. The same group (Yuan et al., 2012), however, reported that rumen protected niacin reduced plasma non-esterified fatty acid concentrations in early lactation.

Several experiments have been reported where blends of B vitamins were given to dairy cows. It would appear that cows only respond when the vitamins are protected from rumen degradation.

Majee et al. (2003) compared an unprotected blend of B vitamins at two concentrations to unprotected biotin and an unsupplemented control ration. A concentration of 20 mg of biotin, whether supplied per se or as a component of the unprotected blend of vitamins, was effective in improving milk yield and milk protein yield over the control. Approximately half of the biotin would be expected to escape degradation in the rumen (Santschi et al., 2005), while most of the remained vitamins in the blend were likely degraded in the rumen.

Studies conducted with rumen protected B vitamins, on the other hand, showed more promise. Sacadura et al. (2008) conducted two studies comparing a B-vitamin blend with a control. In the first study, milk, milk protein yield and milk fat yield increased for mature cows in mid lactation. Only protein yield was increased in a second late lactation experiment involving heifers and cows. In another evaluation, Jurchem et al (2012) demonstrated that the provision of a B vitamin blend to cows until they were confirmed pregnant reduced days to conception. Milk/feed was improved in the experiments reported by Sacadura et al. (2008) and Jurchem et al (2012) when rumen protected B vitamins were added to the diets of lactating dairy cows.

Recently, two large studies were conducted with feedlot cattle. In a feedlot entry study (Leclerc et al., 2015a), the number of days needed to recover transport shrink were reduced for the group of cattle fed the protected B vitamins blend (Table 5). The inclusion of the protected B vitamins blend in the diet improved total gain weight over the 21 day period, average daily gain, and feed/gain. No significant difference was observed between the control and treatment group, for morbidity (2.16 vs. 1.52%) which was low for both groups.

Table 5. Effects of supplementation of a protected B vitamins blend on performance of beef cattle.

	Control	**Protected B vitamins**	**Difference**
Number of cattle	448	451	
Days on feed	21	21	
Initial Weight, Kg	264.60	259.26	5.34
Final Weight, Kg	305.86	305.53	0.33
Total Gain, Kg	42.40^{a}	46.26^{b}	3.860
Average Daily Gain, Kg	2.01^{a}	2.20^{b}	0.190
Feed Intake, Kg	8.53	8.35	0.180
Feed/gain	4.33^{a}	3.90^{b}	0.430
Shrinkage recovery days	16.63^{a}	15.36^{b}	1.27

a,b means with different superscripts differ ($p<0.05$)

There were tendencies for improved feed efficiency in a preliminary finishing trial (Leclerc et al, 2015b) but there were no differences in average daily gain in that study. Additional trials are underway to assess the responses of finishing cattle to supplemental rumen protected B vitamins.

Summary

With the exception of the linkage between thiamin status and polioencephalomalasia in cattle receiving high sulfur diets (Apley , 2015) or ingesting endophyte toxin (Lauriault et al.1990) there are no lesions typical of vitamin deficiencies recognized in dairy and beef cattle. However, there is no denying that vitamin supplementation can improve performance in these animals. Calculations of supply indicate that the levels provided by rumen microbes may not be sufficient to maximize performance, and benefits are derived when these nutrients are added. Vitamins need to be supplied in protected form for most of the vitamins in order to insure delivery to the duodenum. While there is no doubt that meat and milk production will continue to improve, consideration of B vitamin requirements may increase this rate of change in productivity.

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