The Use of Beta Carotene in Dairy Rations

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Prolonged calving intervals and culling losses due to infertility are profit leaks that many dairy farmers want to reduce. Beta Carotene is a management tool that you can use to meet this challenge!

"But why add beta carotene to my client's dairy ration? His feed has vitamin A in it already." This is what a veterinarian asked me.

Vitamin A is indispensable because of its role in ocular function, bone growth, and health of body surfaces, including those of the reproductive tract. The new information is that beta carotene has *specific* functions unrelated to its vitamin A activity. These are functions that vitamin A cannot replace. As the beta carotene intake of a herd becomes marginal, one can expect to see:

- weak and poorly defined estrous activity.
- delayed ovulation.
- decreased concentration of beta carotene in the corpus luteum.
- smaller corpora lutea.
- lower rate of production of progesterone.
- increased incidence of cystic ovaries.
- early embryonic deaths and abortions.
- lower butterfat production.
- decreased vitality of the new-born.

The above findings were found by an interdisciplinary team in Germany when they studied the metabolic aspects of high-producing dairy cows with infertility problems. A review article has been published.[1 2 3 4 5]

Although beta carotene is converted to vitamin A, the reverse is unlikely.[6 7] Thus it is possible, and in fact, common in certain feeding programs that cows will receive adequate vitamin A, but have an inadequate beta carotene intake.

How do we know if a herd is getting enough beta carotene?

Since beta carotene is derived from the diet fed, let us have a look at the contribution made by individual feed stuffs. Bear in mind that a cow producing 60 pounds of milk has a daily requirement of approximately 700 mg of beta carotene.[5]

Fresh green roughages, Table 1,[8] are potent sources of beta carotene, while grains (Table 2)[8] are essentially devoid. Silages (Table 3)[8] contain moderate levels of beta carotene. Since beta carotene deteriorates in the presence of moisture, heat and acidity, it is reasonable that more variability might exist with silages due to storage conditions than exists with

Table 1.

BETA CAROTENE CONTENT OF VARIOUS GREEN ROUGHAGES

	Carotene (mg/lb.)	
Green Roughage	Average	Range
Alfalfa	90.2	33.1 - 177.5
Brome	141.0	30.0 - 264.4
Clover	128.6	34.5 - 253.1
Fescue	153.1	36.3 - 285.8

Table 2.

BETA CAROTENE CONTENT OF VARIOUS GRAINS

	Content (mg/lb.)	
Grain	Average	Range
Corn	1.5	0.1 - 6.0
Corn Dent #2	0.9	*
Sorghum (Milo)	0.2	0.1 - 1.2
Oats	0.0	0.0

* Not published

Table 3.

BETA CAROTENE CONTENT OF VARIOUS SILAGES

	Content (mg/lb.)	
Silages	Average	Range
Alfalfa	40.7	0.2 - 133.3
Corn	7.1	3.6 - 10.5
Alfalfa - Brome	6.2	5.1 - 7.3

other roughages. Cows from one of the case studies to be reported (Farm F) had a very low beta carotene intake, yet were on silage feeding. Alfalfa silage can be a good source of beta carotene, while corn silage is a poor source of beta carotene. Dry roughages (Table 4)[8] can be a fair to excellent source of beta carotene. Hay from legumes can be a potent source of beta carotene. Plant mixture, stage of maturity at cutting and processing procedures all influence beta carotene content. Despite the beta carotene content of a feedstuff at harvest, levels decline steadily (Table 5)[8] with storage.

Table 4.

BETA CAROTENE CONTENT OF VARIOUS DRY ROUGHAGES

Dry Roughage	Content (mg/lb.) Average	Range
Alfalfa Hay	27.7	0 - 321.2
Alfalfa Hay, (s.c.)	17.2	1.1 - 65.0
Alfalfa Dehy. 17%	70.0	0 - 288.4
Alfalfa Dehy. 20%	120.0	*
Clover Hay	30.7	0.5 - 149.1
Alfalfa Timothy Hay	6.0	1.5 - 16.7
Alfalfa - Brome Hay	8.9	4.8 - 16.0

* Not published

Table 5.

BETA CAROTENE LOSSES IN ALFALFA HAY DURING STORAGE

Week of Storage	Carotene Content (mg/lb.)	Carotene Loss (%)
0	11.2	0
4	8.0	29
8	6.6	41
12	4.5	60

* Warm ambient temperatures

In addition to calculations based on the feeding program, the beta carotene status of a herd can be determined by chemical analysis[9] of serum or plasma. Blood plasma levels give an accurate indication of the balance between the amount of beta carotene that is consumed, and the amount that is shed in the milk, stored in the corpus luteum and body fat, or degraded in the body. Figure 1 gives an arbitrary classification, based on a summary of the research findings, that can be used to interpret blood values. Levels above 400 mcg per 100 ml of blood plasma reflect adequate beta carotene intake, while levels between 200 and 400 indicate a marginal intake. Values below 200 mcg/100 ml are definitely low.

If a herd has poor reproductive performance despite good management and a feeding program that is sound with the exception of beta carotene, what can be done?

Here is how supplementation with beta carotene was given on six such farms, with Holstein Friesian cows, and the results that were obtained.

FIGURE I:

B-Carotene
mcg/100 ml blood plasma

	SUFFICIENT
400	
300	SUSPECT
200	
100	CRITICAL
	DEFICIENT

Farm A:[10]

The yearly feeding program for this herd consisted of feeding a rolled barley: protein supplement mixture according to production (ad libitum for certain cows) with free-choice corn silage. Each cow was given 10 pounds of alfalfa hay/day.

This was an extremely high producing herd. The owner produced as much milk with one cow as his father produced with two cows. Unfortunately, this herd was plagued with a high incidence of retained placentae, with metritis as a frequent sequel. In turn, poor conception rates and a high culling rate due to infertility were experienced. Eleven blood samples taken on November 12, 1978, had an average beta carotene content of 237 mcg/100 ml with a range from 123 to 400 mcg/100 ml. Serum vitamin A content was 871 I.U./100 ml, with a range from 322 to 2,684 I.U./100 ml.

A commercial preparation[A] was used to increase the amount of beta carotene in the diet. A premix was made that contained 2250 mg of beta carotene per pound. When this

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[A] *Rovimix® Beta Carotene 10% (Hoffmann-La Roche Limited)* premix was used as a top-dress it was rejected due to "strangeness," but cows readily accepted the material when it was mixed into the grain supplement mixture. Two hundred milligram of additional beta carotene were delivered for each 25 pounds of the mixture consumed. Because retained placentae were a problem in this herd, beta carotene supplementation was given to cows 10 to 14 days before they calved.

Table 6 compares the performance of the herd for a complete year with beta carotene supplementation compared to that of the previous year. There was a dramatic reduction from 48.2 to 4.3 percent in the incidence of retained placentae during the time of beta carotene supplementation. Similarly, there was a reduction in the number of cows that were culled due to infertility. Those animals that were culled during the test period had calved some time before they received additional beta carotene. No cow was culled that received beta carotene supplementation directly after calving. A paired comparison of 17 cows that conceived during both periods showed a reduction by 0.8 of the number of services required per conception, and a shortening of the calving interval by 45 days. Milk butterfat production increased, based on the average of 4 Record of Performance (ROP) tests, by 0.2% during the period of supplementation.

Table 6.

Performance of Herd A Before and After Beta Carotene Supplementation

CRITERIA	REPRODUCTIVE PERFORMANCE - COWS FOR YEAR: Prior to B-Carotene Supplementation	REPRODUCTIVE PERFORMANCE - COWS FOR YEAR: With B-Carotene Supplementation
Cows with retained placentae (%)	48.2	4.3
Services* required per conception	2.6	1.8
Calving interval* (months)	14.1	12.6
Culled due to Infertility	33.3	7.7**
Milk Butterfat (%)	4.0	4.2

* Based on paired comparisons of the first 17 cows to conceive while on beta carotene supplementation.

** These cows calved prior to beta carotene supplementation.

Farm B:

This is the preliminary report of the first year of a study being conducted by D. A. Murray at the Ridgetown College of Agricultural Technology, Ridgetown, Ontario, Canada. This herd has a yearly production of 180 BCA. Throughout the year this herd is fed a grain supplement mixture according to production, corn silage is available ad libitum, and 5 pounds of hay per cow/day are given. The average content of beta carotene was 78 mcg/100 ml of blood, with a range of 36-221 from 16 cows sampled in June 1979. Cows were divided into two test groups and given coded material (beta carotene or vitamin A). Four hundred milligram of beta carotene or the equivalent amount of vitamin A (1 mg = 400 I.U.) was given daily per cow as a top-dress in the dry period beginning approximately 14 days before calving, and one-half this amount after calving until pregnancy was confirmed. As an average, the number of services required per conception (Table 7) was reduced by 0.9, and the number of days open was reduced by 23.2 for the cows that received beta carotene. An infectious disease outbreak during the trial period reduced the reproductive efficiency of this herd.

Table 7.

Performance of Herd B with Beta Carotene Supplementation

Criteria	Control*	Beta Carotene Supplementation
No. of cows	12	13
Services/ Conception	3.5 $\pm$ 7.8	2.6 $\pm$ 1.5
X of days open	134.4 $\pm$ 61.1	111.2 $\pm$ 48.9

D. A. Murray (1980)

* Received 400 I.U. Vitamin A extra for each 1 mg of beta carotene given to other group.

Farm C:[10]

The same trial design that was used in trial B was used on this farm, except that supplements were not given in the dry period. Cows in this herd were given a mixed grain: protein supplement mixture according to production, and were given 30 pounds of corn silage and 20 pounds of hay daily. Average milk production was 14,500 pounds of milk.

Pre-trial assay revealed an average of 182 mcg/100 ml (range 104-310) of serum for 10 cows sampled in the 60-90 day past calving period. In favour of beta carotene supplementation there was (Table 8) a 39% reduction in the number of services required (1.3 services/conception) and 19 more animals were in calf at the end of the test period. This group also had a 0.17% improvement in milk butterfat production, based on the average of 5 R.O.P. tests.

Table 8.

Performance of Herd C with Beta Carotene Supplementation

Criteria	Beta Carotene Supplementation No*	Beta Carotene Supplementation Yes
No. of cows	14	20
No. of cows in calf (%)	10 (71)	18(90)
Services/ Conception	3.3	2.0
Average % butter fat	3.86	4.03

* 400 I.U. Vitamin A given extra for each 1 mg of beta carotene given to other group.

Results for farms D and E[11] are the first reports from the U.S.A. on the use of the commercial product for beta carotene supplementation.

Farm D:

Every other cow was given 300 mg of beta carotene daily in the form of a top-dress. A slight reduction (Table 9) in the average number of days open, and an improvement in the conception rate was noted. Once this trial was started it was found that sterility problems existed which beta carotene would not be expected to correct.

Table 9.

Performance of Herd D with Beta Carotene Supplementation

Criteria	Beta Carotene Supplementation* No	Beta Carotene Supplementation* Yes
No. of Pregnancies	12	12
$\bar{X}$ of days open	120	115
Services/ Conception	2.2	1.6

* Every other cow was given beta carotene.

Farm E:

The breeding performance (Table 10) of 16 cows that received 300 mg per cow per day of additional beta carotene was compared with results obtained in their previous pregnancy. During the period when cows were given supplemental beta carotene, there was a 19% improvement in the first-service conception rate, one less service per conception was required, and cows were in calf 18 days earlier than they were with their previous pregnancy.

Table 10.

Performance of Herd E with Beta Carotene Supplementation

Criteria	Reproductive Performance* Previous Pregnancy	Reproductive Performance* Pregnancy with Beta Carotene Supplementation
$\bar{X}$ of days open	101	83
Services/ Conception	2.5	1.5
First Service Conception Rate	37%	56%

* For 16 cows.

Farm F:[12]

This 35 cow herd had an average milk production of 16,000 pounds, with 4% butterfat. The yearly feeding program was to feed alfalfa haylage, high moisture corn and cob meal and dried distillers grains. Sodium bentonite was top-dressed and is available free-choice.

Despite excellent management, this herd suffered from a poor conception rate, and a long calving interval. Cows would be observed in heat prior to 70 days past calving, the earliest this operator would consider breeding, but despite vigilent heat detection, estrus would not be observed in these cows again until at least 120 days past calving. Then, with a poor conception rate, calving intervals were greatly extended.

Beta carotene blood levels were in the range of 100-200 mcg/100 ml when sampled in February, 1979. Since that time until the writing of this paper, cows have been given 200 mcg of beta carotene supplement by top-dress from calving until confirmed pregnant. Nineteen of the first 30 services (63%) given after beginning supplementation were successful to give a services/conception ratio of 1.57. Table 11 outlines the breeding performance for this herd at the commencement of beta carotene supplementation, and at

Table 11.

AVERAGE DAYS OPEN: HERD F EVALUATION
(April 1979 - June 1980)

Time of Evaluation	No. of Cows	Average Days Open
April 1979	31	153
May 1979	31	156
July 1979	31	155
November 1979	32	160
December 1979	33	136
January 1980	33	135
March 1980	36	124
April 1980	36	120
May 1980	34	121
June* 1980	34	119

Days earned 34 x 41 = 1,394

* Eight of the cows in this evaluation did not receive beta carotene directly after calving.

intervals for the next 14 months. The average number of days open for the last 31 cows to be confirmed pregnant, when evaluated in April, 1979, before any cows were given additional beta carotene, was 153 days. The average number of days open remained unchanged for the next three evaluations, and then began to improve steadily. The last 34 cows confirmed pregnant in this herd were open, as an average, 119 days. However, 8 of these 34 cows had calved for some time before receiving supplement containing beta carotene. The 26 cows that received supplementation directly after calving became pregnant again in 31 services (1.2 services/conception), and were open 92.5 days!

Beta Carotene Requirements and Feeding Recommendations

Table 12 lists the daily beta carotene requirements for cows and heifers as suggested by Lotthammer.[5] These values must be obtained from the feeding program, or, when that is insufficient, by supplementation with beta carotene. It can be seen that beta carotene requirements are similar to those of other nutrients, in that the more a cow produces, i.e. the more beta carotene that is shed in the milk, the more a cow requires. Also like other micronutrients, a cow does not need much beta carotene at a given time, but requires small amounts on a daily basis. Although vitamin A is stored for long periods in the liver the bovine species can become depleted of beta carotene in a matter of days, [13] [14] if not enough is supplied through the diet.

If supplementation is necessary, give approximately 300

Table 12.

Daily Beta Carotene Requirements of Dairy Cows

Heifers and dry cows	300 mg
Lactating 10 litres (22 lbs. daily)	300 mg
" 20 " (44 lbs. daily)	500 mg
" 30 " (66 lbs. daily)	700 mg
" 40 " (88 lbs. daily)	900 mg
" 50 " (110 lbs. daily)	1,100 mg

Lotthammer, 1979.

mg/cow/day (dosage will vary in different situations) beginning 21 days before calving and continuing until the cow is confirmed in calf. Supplementation in the dry period is extremely efficient as none will be lost via the milk; it will be utilized by the cow or shed in the colostrum for the calf. Since the commercial product is quite concentrated (100,000 mg/kg) administration via a premix or a dilution is recommended. These less concentrated materials can be given as a top-dress, added to the supplement, or mixed into the dairy cow ration. Beta carotene is instable in the presence of moisture; steam-pelleting procedures can greatly reduce the potency of a prepartation. Cows are alert to any change around them, so beta carotene supplementation must be introduced gradually into a feeding program to avoid refusal.

Summary:

In the last 2 decades, as tremendous gains in milk production have been made, in many cases, greater financial losses have occurred because cows were open too long or had to be culled due to infertility. During the same time period, we have, as an industry, taken the cow away from beta carotene. We have done this by taking her off pasture, by feeding her stored feedstuffs for a greater part of the year, and by replacing roughages, which contain beta carotene, with grains, which are poor source.

If there is a common denominator for the results of the farms described in this paper, and the research findings, it is that the reproductive processes (ovulation, signs of estrus, development of corpus luteum) are normal when the beta carotene supply is adequate. We have taken beta carotene away from the dairy cow; it is time to put beta carotene back into total herd management!

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