Vitamin A for Dairy Cattle

by L. A. MOORE, HENRY T. CONVERSE, and S. R. HALL

TOO LITTLE vitamin A in rations of dairy cattle leads to difficulties that sometimes a farmer cannot readily tell from ailments produced by other causes. Young calves that do not get enough vitamin A the first 3 or 4 months usually die of scours and pneumonia. If they survive early calfhood and their vitamin A intake is exceptionally low, they are apt to show poor condition, grow slowly, become blind, and have diarrhea and convulsions. Even though enough vitamin A is fed to produce good growth and apparently healthy calves, there still may be a partial deficiency; that can be detected only by directly examining the inside of the eye or by determining the vitamin A content of the blood plasma, which will be low. Cows that get too little of the vitamin reproduce poorly, as denoted by premature births, still-born calves, and retention of the afterbirth. The deficiency must be severe, however, to lower potency of bulls. Other symptoms of vitamin A deficiency are quite noticeable before semen quality and sexual urge are affected.

Except for the first few months of life, depending on the length of the whole-milk feeding period, dairy cattle receive most of their vitamin A in the form of carotene, a yellow pigment in plant material. Carotene is the same pigment that gives the yellow color to carrots and the natural color to butter. In hay and other roughages the yellow color is masked by the green pigments in the plant. The yellow pigment, carotene, sometimes called provitamin A, is changed by the animal body to the true vitamin A, which is almost colorless. The vitamin A in cod-liver oil is the same material as that formed from carotene in the animal body. Young calves receive a considerable supply of the colorless form of vitamin A in the cow's first milk (the colostrum), whole milk, or when their ration is supplemented with cod-liver oil.

At Beltsville calves getting 10 or fewer micrograms of vitamin A daily per pound of body weight died or were subnormal; those getting 17 micrograms were normal

Animal No.	Micrograms vitamin A per pound body weight daily	Percent of normal weight at—					Result
		Birth	30 days	60 days	90 days	120 days	
136–H.....	3. 4	85	69	.....	.....	.....	Died at 75 days.
349–H.....	3. 4	80	81	77	72	74	Died at 175 days.
431–J.....	4. 5	97	82	69	.....	.....	Died at 63 days.
1906–J.....	4. 5	123	99	95	89	89	Deficiency symptoms.
348–H.....	7. 0	116	90	85	85	85	Slow growth.
1909–J.....	10. 3	80	74	65	55	42	Continuous scours
1758–H.....	10. 3	100	.....	.....	.....	.....	Died at 21 days.
246–H.....	[1] 17 (25)	94	85	87	98	101	Normal.
247–H.....	[1] 17 (25)	91	80	83	87	91	Do.
415–J.....	[1] 48 (110)	80	95	101	98	104	Do.
316–J.....	[1] 48 (110)	100	103	107	115	110	Do.

[1] Two calves, 246–H and 247–H, received 10 milliliters of cod-liver oil daily for an average intake of 17 micrograms of vitamin A per pound for 6 months or an average of 25 micrograms for the first 2 months; 415–J and 316–J received 20 milliliters of cod-liver oil daily in the same manner.

Quantities of vitamin A and carotene are usually expressed in terms of micrograms, a unit of weight that denotes one-millionth of a gram or about one twenty-eighth of a millionth of an ounce. One can readily appreciate the extremely small quantities of material with which we are dealing when we talk about vitamins. The term "International unit," abbreviated I. U., also is used. One I. U. equals about 0.25 microgram of vitamin A or 0.6 microgram of Beta-carotene in biological activity. A milliliter, another unit used in measuring volumes, equals about one-fifth of a teaspoon.

Calf Diets Have Changed

Present-day methods of raising dairy calves with limited amounts of whole milk have considerably altered the quality and quantity of food that a young calf receives, compared with what calves received in the wild state.

What happens is told in reports from several State agricultural experiment stations.

Maryland: When calves were fed limited amounts of whole milk, the vitamin A content of the blood plasma from birth to 4 months of age was in the deficient range, as judged by blood values of older calves that had too little vitamin A.

This table, based on studies at Beltsville, shows the amounts of vitamin A and carotene required to prevent losses from scours and pneumonia in calves, due to vitamin A deficiency. Also shown is the amount of cod-liver oil and average amount of alfalfa hay needed to meet the requirements. These values are based on the assumption that in cattle carotene is required in the ratio of 1 part of vitamin A to 4 parts of carotene on the weight basis or 1 to 2 on the International unit basis

Age (months)	Weight	Vitamin A		Carotene		Cod-liver oil	No. 2 alfalfa hay
		Total	Per pound of body weight	Total	Per pound of body weight		
	Holstein calves						
	Pounds	*Micro-grams*	*Micro-grams*	*Micro-grams*	*Micro-grams*	*Milli-liters*	*Pounds*
1	110	3, 780	34	14, 500	132	7. 0	2. 1
2	136	3, 276	24	12, 586	93	6. 0	1. 9
3	174	2, 945	17	11, 310	65	5. 5	1. 7
4	224	2, 310	10	8, 874	40	4. 3	1. 3
	Jersey calves						
1	64	2, 270	34	8, 680	132	4. 0	1. 3
2	85	2, 009	24	7, 714	93	3. 7	1. 1
3	111	1, 890	17	7, 250	65	3. 5	1. 1
4	147	1, 494	10	5, 742	40	2. 8	. 9

Michigan: The vitamin A content of the blood plasma of dairy calves getting limited quantities of whole milk was one-third lower than that of beef calves of the same age that obtained considerable whole milk by suckling.

Ohio: The incidence of pneumonia declined in calves that received 15,000 I. U. of vitamin A concentrate daily.

Minnesota: Less trouble from digestive disturbances was encountered in young calves fed cod-liver oil than in calves not receiving the supplement. Whole milk was fed at the rate of one-eighth of the body weight for the first 30 days, followed by skim milk to 6 months of age. While both groups had scours, some of the calves that had no supplement died.

Wisconsin: The administration of shark-liver oil, of high vitamin A potency, plus certain of the B vitamins, eliminated diarrhea and lowered the number of deaths from pneumonia.

Michigan: Young calves invariably died of pneumonia and scours when placed on a vitamin-A-deficient ration.

Beltsville: Calves on a low vitamin A intake all died before they were 100 days old.

The reports suggest that vitamin A may have something to do with the building-up of an immunity against bacterial infections in young calves.

H. T. Converse and E. B. Meigs, in studies at Beltsville, used a ration low in vitamin A, consisting of skim milk, grain, and late-cut brown timothy hay. Their results indicate that a minimum intake of between 10 and 25 micrograms of vitamin A per pound of body weight a day is necessary to maintain normal growth.

It is possible that vitamin A is more important to a herd in which the organisms that cause pneumonia and scours are present than to one where the organisms are absent or nonvirulent. In the latter case, a very low intake of the vitamin might cause no difficulty. In evaluating the tests and results, therefore, these points must be kept in mind.

It seems that the minimum quantity of vitamin A needed per pound of body weight to maintain good health, growth, and a normal level of vitamin A in the blood lies between 18 and 34 micrograms a day per pound of body weight. If an arbitrary average of 25 is chosen, and this figure doubled for optimum results under practical farm conditions, a 100-pound calf would require 5,000 micrograms of vitamin A or about 20,000 I. U. a day.

How can these requirements be met practically? First of all, because a cow's first milk after calving, or colostrum milk, is very high in vitamin A, calves should be left with the cow or fed the colostrum milk for the first 3 days. The following tabulation, based on studies at the Maryland Agricultural Experiment Station, shows the effect of colostrum on the blood-plasma vitamin A and carotene of newborn Holstein calves:

Age (days)	*Number of animals*	*Vitamin A (micrograms)*	*Carotene (micrograms)*
0 (birth)	17	3. 3+0. 48	1. 8+0. 11
1	17	15. 6+1. 80	14. 9+0. 64
2	16	16. 8+1. 34	17. 4+0. 63
3	17	15. 9+1. 32	18. 8+0. 59
4	16	15. 0+1. 44	19. 1+0. 77
5	15	14. 4+1. 47	18. 7+0. 56
6	16	13. 2+1. 26	17. 4+0. 44
7	13	13. 8+0. 84	16. 5+0. 41

The blood plasma is very low in vitamin A at birth, but the colostrum milk causes about a fivefold increase.

T. S. Sutton and H. E. Kaeser, of the Ohio station, report that colostrum milk furnishes the generous supply of 32,100 I. U. a day for the first 3 days of the calf's life. At Beltsville we found that the vitamin A content of colostrum milk varies with the carotene intake of the cow. Cows on pasture yielded colostrum milk up to 12 times richer in vitamin A than cows that had No. 3 grade of timothy hay. Many dairy farms discard the extra colostrum milk, a wasteful practice.

After the colostrum period, whole milk is usually fed at the rate of about 1 pound per 10 pounds of body weight, but this amount is gradually decreased after 30 days. Average winter milk contains about 640

This table shows the effect of feeding whole milk instead of colostrum for the first few days of a calf's life. One Holstein calf died when 10 days old; the Guernsey was sick at 2 days and died at 3 days of age. The data are based on studies at the Maryland Agricultural Experiment Station

Age in days	Amount per 100 milliliters of plasma					
	Holstein		Holstein		Guernsey	
	Vitamin A	Carotene	Vitamin A	Carotene	Vitamin A	Carotene
	Micrograms	*Micrograms*	*Micrograms*	*Micrograms*	*Micrograms*	*Micrograms*
0	2.7	2.0	0.6	1.0	3.6	4.0
1	3.0	3.0	1.8	1.0	3.9	4.0
2	3.3	4.0	1.5	3.0	.....	.....
3	3.9	6.0	3.9	5.0	.....	.....
4	6.0	8.0	1.8	4.0	.....	.....
5	4.6	6.0	1.2	9.0	.....	.....
6	4.5	8.0	3.0	7.0	.....	.....
7	6.9	10.0	2.7	9.0	.....	.....

I. U. a pound, according to a national survey by the Department. Thus, a 100-pound calf receiving a maximum of 10 pounds of whole milk a day would receive 6,400 I. U. a day. A calf up to 4 weeks of age consumes little hay, so that the intake of vitamin A from the whole milk would not appear to be adequate, when compared with a requirement of 20,000 I. U. If the calf is weaned or changed from whole milk to skim milk at 6 to 8 weeks of age, the total supply of vitamin A must come from the carotene in the roughage. If the roughage is of poor quality, it is doubtful whether the intake of vitamin A is adequate.

There may, therefore, be a need for supplementation of the young calf's ration if the quality of hay is low. The amount and method remain to be established. Conflicting data come from several States about the use of capsules containing 5,000 I. U. of vitamin A plus niacin and ascorbic acid. Until we get further information, then, it seems best to recommend 20,000 to 25,000 I. U. for young calves for the first 4 to 6 weeks where difficulty with scours and pneumonia is encountered. That amount is contained in about three-fourths of an ounce of ordinary cod-liver oil for animal feeding. Calves will consume sufficient hay of good quality (after the first or second month) to meet the requirements.

Of course, just giving a calf extra vitamin A will not overcome poor management. It is still as necessary as ever to have the pails clean, to feed regularly, and to give the calves the right quantities of milk at the correct temperature. Pens must be dry, bedding ample, and stalls free from draughts.

Some research workers suggest that young calves cannot utilize caro-

tene efficiently. But among the calves raised at Beltsville without whole milk after the colostrum period of about 3 days were 50 calves that received no vitamin A as such, except from the colostrum. These calves, which made adequate gains, received skim milk with a carotene supplement starting on the third or fourth day after birth and continuing to at least 6 months of age. Thirty of them received carotene as carotene in oil, and 20 had grated or finely ground garden carrots as the source of carotene. Calves fed skim milk after the colostrum period but without any vitamin A or carotene supplement died before 100 days of age.

Carotene is the only natural source of vitamin A for growing dairy cattle after they no longer receive any whole milk. The minimum requirements as found by different investigators vary considerably depending upon the criteria used: A summary of these requirements is given in the table at the top of the next page.

Of course, the amount of hay or silage necessary to meet minimum requirements depends upon its carotene content. Several workers at Beltsville determined that various kinds of roughage differ widely between grades and have a wide range of carotene content within grades, as shown by the following tabulation, in which the carotene content is expressed in micrograms of carotene per gram as fed:

Kind of Feed	*Average*	*Range*
Alfalfa hay:		
Grade U. S. No. 1 in color	43	19–121
Grade U. S. No. 2 in color	15	12–20
Grade U. S. No. 3 in color	4	1–11
Timothy hay:		
Grade U. S. No. 1 in color	21	8–36
Grade U. S. No. 2 in color	9	8–11
Grade U. S. No. 3 in color	5	1–12
Corn stover (dry)	4	2–6
Corn silage	14	1–40

Under practical conditions the minimum carotene requirement should at least be doubled. If 30 micrograms of carotene per pound of body weight is considered about a minimum and this figure is doubled, the amount of hay of various grades to be fed to cattle of various weights can be obtained from the facing table. The carotene content of the average hay on dairy farms approximately equals that of No. 2 hay.

Vitamin A deficiency in growing dairy cattle under practical farm conditions probably does not occur often. But it has been observed when the dairyman feeds too much grain in proportion to roughage, in an attempt to get rapid growth; in drought years when the range is short and of poor quality; and in the feeding of poor or a limited quantity of roughage for a long time. A brown late-cut timothy hay, a 2-year-old hay, or No. 3 quality hay would fall in this classification.

We learned at Beltsville that cows that get 80 to 100 milligrams a day of carotene give birth to normal calves. A. H. Kuhlman and W. D. Gal-

Tests made at various stations show that growing calves need from 14 to 57 micrograms of carotene each day per pound of body weight. This table also shows the amount of average alfalfa hay needed to meet these requirements

Station	Required carotene per pound of body weight	Breed and criteria used	Pounds of average hay needed per 100 pounds body weight
	Micrograms		*Pounds*
California	14	Beef cattle (night blindness)	0. 21
Texas	20	Beef cattle (physical condition)	. 29
Michigan	16	Holstein (night blindness)	. 24
Wisconsin	34	Holstein (blood vitamin A)	. 50
Do	57	Guernsey (blood vitamin A)	. 84
Pennsylvania	27	Guernsey and Holstein (blood vitamin A)	. 40
Maryland and Michigan.	30	Holstein (spinal fluid pressure)	. 44
Maryland	34	Guernsey (spinal fluid pressure)	. 50

lup, working with Jersey cows at the Oklahoma Agricultural Experiment Station, considered a daily intake of 40 to 45 micrograms of carotene per pound of body weight about the minimum needed for normal calving. Large quantities of poor hay must be fed in order to meet the requirements, but only a small portion of good roughage is necessary. Good pasture furnishes an excellent supply of carotene and is the best roughage available for this purpose.

The possibility of a relationship between vitamin A intake and ascorbic acid metabolism and reproduction has been suggested. P. H. Phillips and

A good practice is to feed a growing dairy cow at least twice as much carotene as she must have. This can be done by feeding various weights of cattle these amounts

Grade of hay	Carotene content	Quantity of hay		
		200-pound animal	500-pound animal	800-pound animal
	Micrograms per gram	*Pounds*	*Pounds*	*Pounds*
No. 3	2	13. 2	33. 1	52. 9
	4	6. 6	16. 6	26. 4
	8	3. 4	8. 2	13. 2
No. 2	12	2. 2	5. 5	8. 9
	16	1. 7	4. 2	6. 6
	20	1. 3	3. 3	5. 3
No. 1	24	1. 1	2. 8	4. 4
	30	. 9	2. 2	3. 5
	50	. 5	1. 3	2. 1

A cow needs an ample supply of carotene to produce normal calves. The amounts given here are double the minimum required, but are recommended for best results

Grade of hay	Carotene content	Quantity of hay			
		800-pound animal	1,000-pound animal	1,200-pound animal	1,400-pound animal
	Micrograms per gram	*Pounds*	*Pounds*	*Pounds*	*Pounds*
No. 3	2	106	141	159	185
	4	53	70	80	97
	6	35	44	53	62
No. 2	12	17	22	26	31
	16	13	17	20	24
	20	11	14	16	19
No. 1	24	9	11	13	16
	30	7	9	11	12
	50	4	5	6	7
Corn silage	15	14	18	21	25
Grass silage	50	4	5	6	7

his associates at the Wisconsin Agricultural Experiment Station reported lower blood plasma and urine ascorbic acid values in a calf on a vitamin-A-deficient ration than in a check animal that received 100 micrograms of carotene per kilogram of body weight. Later, they found that the feeding of a high potency shark-liver oil to certain dairy herds in a breeding cooperative caused the animals to maintain more nearly normal ascorbic acid values in the blood plasma. In studies conducted at the Maryland station it was found that ascorbic acid excretion was depressed in severe vitamin A deficiency, but not in moderate deficiency. These data raised the question of whether, under practical conditions, the vitamin A intake is not always sufficient to prevent any marked depressing effect on ascorbic acid synthesis. If there were a deficiency it would indirectly affect reproduction. Vitamin A deficiency does affect reproduction; severe deficiency will cause sterility or poor conception rates, but a study of the available scientific data does not lead to the conclusion that this would be true under practical farm conditions. The scientists at the Oklahoma station obtained a satisfactory conception rate when the carotene intake was at the same level as that required for normal calving. Data collected at Beltsville do not indicate that the conception rate was any lower for cows on poor hay than for those on good hay.

The need of bulls for carotene for proper reproductive performance has not been worked out in detail. Experiments with various species of animals, including the bull, have shown that vitamin A deficiency causes a degeneration of the germinal epithelium of the testicles. At Beltsville semen capable of fertilizing cows was produced by young bulls that had

developed rather severe symptoms of vitamin A deficiency, such as blindness, incoordination, weakness, or diarrhea. The intake of these bulls was less than 10 micrograms of carotene per pound of body weight. Blindness will usually develop in growing bulls on an intake of 10 micrograms or less of carotene per pound of body weight. Although the semen of the bulls at Beltsville could impregnate cows, it did not maintain motility after storage, was low in concentration of sperm, and was in general of poor quality. Nor did the young bulls kept on these low intakes start to breed at the normal age. This sexual retardation appeared to depend on the age at which the bulls developed vitamin A deficiency.

According to data collected at the Maryland station, young bulls 12 to 14 months old reared on intakes of carotene varying from 10 to 34 micrograms per pound of body weight and kept outside during the heat of the summer showed marked histological alterations in the testicles. Increasing the intake of carotene to 100 micrograms per pound of body weight brought about marked improvement.

It seems unlikely, under practical farm conditions, that vitamin A will be a limiting factor of great importance in affecting the reproductive performance of bulls. It does seem likely that if hay were fed to them in the same quantities as for growing dairy cattle, the intake of carotene would be sufficient to maintain proper reproductivity in bulls.

THE AUTHORS

L. A. Moore, in the Bureau of Dairy Industry, has made several outstanding contributions in dairy cattle nutrition, his greatest being the correlation of increased cerebrospinal fluid pressure with vitamin A deficiency. He has also developed a method for determining the amount of carotene in hay and silage and has studied the effect of maturity on the carotene of some of the common hays and pasture plants.

Henry T. Converse, in the same Bureau, has investigated vitamin A requirements for growth, lactation, and reproduction in dairy cattle; calcium requirements for growth and milk production; and the role of some other vitamins than vitamin A in calf growth.

Among the important investigations made by S. R. Hall in the Bureau of Dairy Industry has been the effect of the low vitamin A in the ration on the anterior pituitary gland and reproduction in cattle.

FOR FURTHER READING

Converse, H. T., and Meigs, E. B.: *The Vitamin Requirements for Normal Growth in Young Dairy Cattle,* American Society of Animal Production, Proceedings, 32d Annual Report, pages 67–72, 1939.

Erb, R. E., Andrews, F. N., Bullard, J. F., and Hilton, J. H.: *A Technique for the Simultaneous Measurements of Semen Quality and Testes Histology in Vitamin A Studies of the Dairy Bull,* Journal of Dairy Science, volume 27, pages 769–772, 1944.

Gullickson, T. W., and Fitch, J. B.: *Effect of Adding Cod Liver Oil to the Rations of Dairy Calves,* Journal of Dairy Science, volume 27, pages 331–335, 1944.

Jones, I. R., Haag, J. R., and Dougherty, R. W.: *The Relation of Nutrition to Breeding Performance in Dairy Bulls,* Journal of Dairy Science, volume 25, pages 689–690, 1942.

Krauss, W. E., Monroe, C. F., and Hayden, C. C.: *The Value of Milk Fat Substitute-Skimmilk Combination for Raising Bull Calves for Veal and Heifer Calves for Replacement,* Ohio Agricultural Experiment Station Special Circular 57, 1939.

Kuhlman, A. H., and Gallup, W. D.: *Carotene Requirements of Dairy Cattle for Reproduction,* American Society of Animal Production, Proceedings, pages 67–73, 1940.

Lewis, J. M., and Wilson, L. T.: *Vitamin A Requirements of Calves,* Journal of Nutrition, volume 30, pages 467–477, 1945.

Lundquist, N. S., and Phillips, P. H.: *Certain Dietary Factors Essential for the Growing Calf,* Journal of Dairy Science, volume 26, pages 1023–1030, 1943.

Moore, L. A., and Berry, M. H.: *Effect of Colostrum on the Vitamin A and Carotene Content of Blood Plasma of New-Born Calves,* Journal of Dairy Science, volume 27, pages 867–873, 1944.

Moore, L. A., and Berry, M. H.: *Vitamin A and Carotene Content of the Blood Plasma of Dairy Calves from Birth up to Four Months of Age,* Journal of Dairy Science, volume 28, pages 821–826, 1945.

Nelson, H. F., Moore, L. A., Horwood, R. E., and Branaman, G. A.: *Vitamin A and Carotene Content of the Blood Plasma of Beef and Dairy Calves from Birth to Four Months of Age,* Michigan Agricultural Experiment Station Quarterly Bulletin, volume 27, pages 27–28, 1944.

Phillips, P. H., Boyer, P. D., Lardy, H. A., and Lundquist, N. S.: *Vitamin A Levels in the Blood Plasma of Dairy Cattle on Winter Rations and the Influence of Vitamin A Supplementation on Certain Constituents of the Blood,* Journal of Dairy Science, volume 24, page 522, 1941.

Phillips, P. H., Lundquist, N. S., and Boyer, P. D.: *The Effect of Vitamin A and Certain Members of the B Complex upon Calf Scours,* Journal of Dairy Science, volume 24, pages 977–982, 1941.

Sutton, T. S., and Kaeser, H. E.: *Some Physiological Effects of Extending the Colostrum Feeding Period of Dairy Calves;* Journal of Dairy Science, volume 29, pages 13–27, 1946.

ALSO, IN THIS BOOK

New Ideas in Feeding, by N. R. Ellis, page 95.
More Vitamin A in Milk, by R. E. Hodgson, H. G. Wiseman, and W. A. Turner, page 143.
What to Feed a Cow, by R. E. Hodgson and W. J. Sweetman, page 149.