Seasonal changes may cause vitamin A deficiency in range heifers

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Range cattle obtain vitamin A from carotenoids in green plants. In northern California's foothill ranges, carotenoids are destroyed as forage dries in the summer. Tests of liver and blood plasma in grazing cattle indicated that mature breeding cows can store enough vitamin A during the green season to meet later needs. Heifers on their first calf, however, may need vitamin A supplementation.

California's combination of winter rainfall and dry summers favors the dominance of summer-dormant annual pasture plants. Cattle on these pastures graze dry forage for a large part of the year. Because summer sunshine and high temperatures destroy carotenoids (the precursors of vitamin A) in dry forages, cattle receive diets deficient in provitamin A and have to draw on their reserves of this vitamin in the liver.

In the early 1930s, G. H. Hart and H. R. Guilbert investigated the vitamin A status of range cattle in California. They reported that 67% to 93% of the vitamin A was in the liver and that range cattle accumulated vitamin A reserves during the green season that were used in the dry season to supply their needs. The researchers recommended providing grazing cattle with good-quality alfalfa hay as a supplement in summer to prevent vitamin A deficiency. More recently, since low-cost synthetic vitamin A has become available, regular supplementation of range cattle has frequently been advocated.

We conducted a 3-year study examining the need to supplement breeding female cows with vitamin A under northern California range conditions. Because cattle can obtain carotene from any green plant, the study site had to be free of all green plants, such as brush, or any areas where water from natural springs or water troughs kept plants green during the summer.

Procedures

Fall-calving cows were used in all 3 years of the study. In the first year, blood plasma and liver concentrations of vitamin A and carotene in 12 Hereford or Hereford cross cows (3 to 6 years old) were measured repeatedly to define annual cyclic changes. Ten measurements, an average of 33.5 days apart, were made from January 26 to December 16, 1981.

In the next 2 years, liver and plasma concentrations of vitamin A in groups of females (13 first-calf heifers in year 2 and 12 cows in year 3) were measured at the end of the green season (June) and immediately before the next green season (October). Heifers were used in year 2, because this class of breeding female could be more susceptible to vitamin A depletion than mature cows.

The cows and heifers were maintained on partially cleared foothill range seeded with subterranean and rose clovers on the UC Sierra Foothill Range Field Station, near Marysville. In the first year, the cows were fed cottonseed meal (carotene-free) as a supplement during the late summer and fall. In the second and third years, the cattle were pastured on the same type of range, but only the heifers received cottonseed meal. The fields were free of brush and had no creeks, springs, or seepages that could have supported green grass or forbs. Water was supplied in troughs.

Samples of the standing dry forage were taken each year before the fall rains and analyzed for beta-carotene. The average beta-carotene concentration in the forage was 1.73 milligrams per kilogram (mg/kg) (plus or minus a standard error of 0.18) dry matter, which is grossly deficient for range cattle.

Blood samples were collected from the animals and the plasma separated by centrifugation before analysis. Liver biopsy samples were frozen, then pulverized and the vitamin A and carotene extracted. Liver biopsy samples had been shown previously in an Australian study to give values comparable to those obtained by analyzing the whole liver for vitamin A concentration.

Liver and plasma vitamin A and carotene concentrations from the first year were analyzed for statistical significance on a yearly and seasonal basis. For the second and third years, statistical analyses compared values at the beginning and end of the dry seasons.

Results

Liver vitamin A. Over the sampling periods in the first year, there was a trend for vitamin A concentrations in liver to decrease, indicating that the liver stores were mobilized during the dry season (fig. 1). The minimum concentration of vitamin A in liver, which occurred in the sampling immediately before the fall rains, was 101.5 (±8.2) micrograms per gram (μg/g). This indicates that at no time in the first year were cows deficient in vitamin A.

Concentrations of vitamin A in liver were significantly lower in the fall of year 1 than in the rest of the year (table 1). The gradual depletion of liver vitamin A stores was presumably associated with the low carotene intake during the dry season. Some animals showed relatively low liver vitamin A concentrations. But no clinical signs of vitamin A deficiency appeared during the study, and all animals entered the mating season in apparent good health after having calved normally.

Liver concentrations of vitamin A declined to a lower level in heifers in year 2 than in mature cows in years 1 and 3. In cows, the average liver concentration was 226 μg/g at the start of winter in year 1 and had decreased by 38% by the next fall. Heifers' concentrations of liver vitamin A dropped 41% in year 2, which was comparable to the depletion in cows in year 1. However, heifers had much lower concen-

TABLE 1. Vitamin A and carotene concentrations in liver and plasma of grazing cattle, Sierra Foothill Range Field Station

Year and season	Liver				Plasma			
	Vitamin A		Carotene		Vitamin A		Carotene	
	Mean*	±SE	Mean*	±SE	Mean*	±SE	Mean*	±SE
	μg/g				μg/dl			
Year 1:								
Winter	188.9 a	12.2	9.6	0.80	24.6 a	0.94	412.4 c	20.7
Spring	172.3 a	15.1	11.3	0.99	22.2 a	1.27	226.5 bc	32.3
Summer	146.8 a	14.1	12.9	1.52	18.6 b	0.80	24.4 b	3.3
Fall	117.3 b	6.7	9.2	0.72	25.3 a	0.83	735.2 a	68.2
Year 2:								
Start dry	157. a	22	15.0 a	1.9	23.9 a	2.5	210. a	18
End dry	96. b	17	8.5 b	1.0	35.1 b	3.1	29. b	1.6
Year 3:								
Start dry	237	25	16.5	1.1	30.2	5.0	619. a	74
End dry	230	30	14.2	3.9	32.7	4.1	401. b	30

* Means for the same year within columns followed by different letters are significantly different at $P < 0.01$.

trations (157 μg/g) at the start of the dry season in year 2 than did cows in year 1 (226 μg/g) or year 3 (237 μg/g). Liver concentrations of vitamin A at the end of the dry season were therefore lower in heifers in year 2 than in cows in year 1 or 3. The small decline in cows' liver vitamin A in year 3 was apparently a result of a higher intake of carotene in year 3 than in year 1.

When animals are given deficient diets, the rates at which they deplete their liver reserves of vitamin A have been shown to be proportional to the total quantity of vitamin A in their livers: the more vitamin A in the liver, the more is used per unit of time. Although heifers showed no clinical signs of vitamin A deficiency, the lower liver reserves indicate that these females could be at greater risk of developing a deficiency than mature cows. The liver has an immense storage capacity that functions both as a reserve during periods of vitamin A depletion and a mechanism for disposing of excess dietary vitamin A, which can be toxic to the animal.

Liver carotene. Liver carotene concentrations are presented for the 10 sampling periods of year 1 in figure 2, and values for the two samplings in years 2 and 3 are in table 1. The average annual liver carotene concentration in year 1 was 10.2 μg/g, which was comparable to that in years 2 and 3. Most mammals do not accumulate carotene in their tissues. Bovines consuming diets rich in carotenoids, however, may accumulate large amounts in the fat, plasma, and milk, with only minimal amounts stored in the liver.

The extent of the conversion of carotene to vitamin A aldehyde (retinal) outside the intestine in cattle has not been determined. The enzyme responsible for the conversion of carotene to retinal occurs in the liver and in the intestinal mucosa. However, in rats the enzyme is four to seven times more active in the intestinal mucosa than in the liver.

Plasma vitamin A. The annual average concentration of plasma vitamin A in year 1 was 22.5 μg/dl; values ranged from 10 to 38 μg/dl. Concentrations in the next 2 years remained within the same range, although individual values were more varied (12 to 54 μg retinol/dl). These values are consistent with the conclusion of other researchers that mammals maintain blood vitamin A levels in the range of 20 to 35 μg/dl.

In the first year, plasma vitamin A was lowest in late spring-early summer (fig. 1). On a seasonal basis, plasma vitamin A was significantly lower in the summer than during the other seasons (table 1), presumably because of the limited amount of carotene in the dry pasture. Based on these results, we selected the two sampling periods for years 2 and 3.

Plasma vitamin A concentrations increased in the fall, despite a further decline from the summer in liver vitamin A concentration. The marked increase of plasma carotene in the fall (fig. 2) indicates that this period coincided with a significant dietary intake of carotene.

In year 2, the plasma vitamin A concentration was significantly greater at the end than the beginning of the dry season, despite the decrease in liver vitamin A. The same pattern occurred in year 3, but the differences were not significant.

The release of vitamin A alcohol (retinol) from the liver to the plasma is controlled by the synthesis of a specific transport protein (retinol binding protein). This protein transports retinol around the body. The rate of synthesis of this protein is affected by diverse dietary and hormonal factors.

Plasma carotene. In year 1, plasma carotene levels fluctuated significantly during the year (fig. 2). Plasma carotene was significantly related to rainfall (which affected plant growth) in the sampling period. Carotene levels in plasma are dependent on the carotene content of the diet. There were significant differences among the seasonal averages (table 1).

During the dry season, the plasma carotene concentration in a few cows reached undetectable levels (less that 8 μg/dl). We interpreted this as a reflection of carotene intake not vitamin A deficiency, since carotene is not the active form of the vitamin. The annual average concentration for plasma carotene was 375 μg/dl, which is comparable to the concentration reported by other researchers for range cattle.

The carotene content of plasma from heifers in year 2 showed a decline over the summer similar to the decline during year 1 in mature cows. In year 3, plasma carotene levels declined only slightly over the summer, indicating that these cows were receiving more carotene in their diet than the cattle in years 1 and 2. This observation is also consistent with the smaller percentage decline in liver vitamin A in cows over the dry period in years 1 and 3.

The plasma carotene concentrations over the 3 years (from less than 8 to 1,470 μg/dl) are comparable to those reported by other researchers for range cattle. The very wide range can be attributed to the variability in the carotene content of the pasture during the year, although some of the variation may have been due to differences between breeds and between individuals.

We calculated simple correlations between concentrations of vitamin A and carotene in liver and plasma, but none of the correlations were significant. Our results support the general conclusion that, when animals are not deficient in vitamin A, the concentration of vitamin A in plasma is a poor predictor of liver concentration. When vitamin A is depleted in animals, however, there is a closer association between liver and plasma vitamin A concentrations.

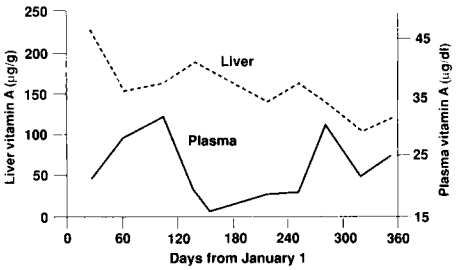

Fig. 1. Average vitamin A concentration in livers of grazing cattle tended to decrease over the first year, but in plasma was lowest in late spring-early summer.

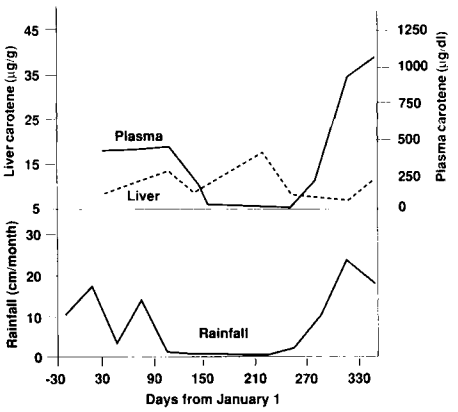

Fig. 2. In year 1, average carotene concentration in the liver was unaffected by season, but in plasma was closely related to rainfall during the sampling period.

Conclusions

Our results suggest that mature breeding stock, under normal range conditions in northern California, can store enough vitamin A in their livers during the green season to meet their demands throughout the year. As they enter the dry season, heifers on their first calf may have lower reserves of vitamin A in their livers than do mature cows. Because a deficiency of vitamin A in breeding females has serious economic consequences, heifers calving at 2 years of age should be given first priority in any vitamin A supplementation program.

The probability of vitamin A deficiency occurring in adult cattle that are grazing pastures seeded with annual clovers appears relatively remote. However, unimproved pastures or pasture species different from those our cattle grazed may give different rates of vitamin A depletion.

James Morris is Professor, and Teresa Iglesias and Myung-Hee Kang were former graduate student and post-doctoral fellow, respectively, in the Departments of Animal Science and Physiological Sciences, University of California, Davis.