FURTHER STUDIES ON THE VITAMIN A REQUIREMENTS OF BEEF CATTLE

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INTRODUCTION

The importance of vitamin A for beef cattle has been recognized for some time. Vitamin A as such does not occur in plants but is formed in the animal body from plant carotenoids. Plants contain different carotenoids that possess vitamin A activity, beta carotene being the most active and the one of most importance in beef cattle nutrition. In general, green leafy plants and yellow seeds and roots are very good sources of carotene. Low quality roughages such as weathered grass, bleached hay and cottonseed hulls are poor sources of carotene and should be supplemented with carotene or vitamin A if they are fed as the only roughage for cattle over a long period of time.

In "normal" seasons, the carotene requirement of beef cattle may be met by range grass. Mature cattle on summer range grass are able to accumulate large body stores of vitamin A for use during the winter. However, during periods of prolonged drouth in the Southwest, the vitamin A problem becomes acute, particularly for young cattle whose vitamin A reserves are usually low.

Although the literature contains many references concerning the carotene and vitamin A nutrition of beef cattle, many questions remain unanswered. Studies of a long-time nature on the importance of vitamin A in beef cattle nutrition have been underway at this station since 1946. From these studies, it appears that in cow-calf

operations, an adequate supply of carotene for the cow during lactation in order to protect her calf may be a critical item. Therefore, an experiment was undertaken to study the effect of three levels of carotene intake during lactation on the vitamin A nutrition of the beef cow and her calf. Studies were also conducted on the blood and liver vitamin A levels of fattening steer calves receiving different amounts of carotene from natural feeds. Observations were made on the relationship of plasma vitamin A and carotene to liver vitamin A stores in beef cattle.

REVIEW OF LITERATURE

Hart and Guilbert (1933) reported that heavy losses occurred during a dry summer in California when cows were maintained the previous winter on dry range grass. Under these conditions calves were born dead or weak and many died shortly after birth. Calves nursing cows low in vitamin A grew slowly and developed clinical symptoms at 10 to 12 weeks of age. Most common symptoms observed in the mature animals were night blindness, ulceration of the cornea, unthrifty appearance, intermittent diarrhea and pulmonary complications. The most common cause of death was pneumonia. After green forage was made available for a short while, the losses ceased and the remaining cows calved normally.

Guilbert and Hart (1935) further demonstrated that temporary night blindness caused by a vitamin A deficiency would become permanent if the cows or calves were not given carotene or vitamin A soon after the onset of the disorder. They concluded that cows could maintain their liver stores and produce normal calves if they were given the equivalent of 1.0 to 1.5 mg of carotene per 100 lb of body weight during gestation and 4.0 mg per 100 lb body weight during lactation.

Semb et al. (1934) stated that the output of carotene in the milk of dairy cows was poor even in cases where the plasma carotene

was high. With Holstein cows, only 0.8 percent of the plasma carotene was converted to milk carotene daily.

Madsen and Davis (1949) studied the effect of various levels of carotene supplementation on gestation and lactation performance of Hereford and Shorthorn cows for a continuous period of 12 years involving several generations. They found that cows, which failed to produce normal calves when they received the equivalent of 1.4, 2.0, or 2.7 mg of carotene per 100 lb of body weight, reproduced normally when they were given 4.0 mg of carotene per 100 lb of body weight. They concluded that when the vitamin A plasma level dropped below 18 mcg per 100 ml, the possibility of a cow producing a normal calf was poor.

Wayne and Kingman (1947) studied the plasma carotene levels of first-calf range Hereford heifers and aged range Hereford cows. They suggest that in order to support normal gestation, the carotene blood plasma level of first-calf range Hereford heifers must be at least 118 mcg per 100 ml while 82 mcg per 100 ml is an adequate level for range Hereford aged cows.

Wheeler et al. (1957) maintained mature Hereford cows on rations supplying 1.5, 5, 15, and 25 mg of carotene per 100 lb of body weight daily. Plasma and liver carotene showed a direct relationship to carotene intake. None of the various levels of carotene intake were sufficient to maintain vitamin A liver stores. Night blindness was produced in the calves within one month of age when their dams received only 1.5 or 5 mg of carotene per 100 lb of body weight. Roberts et al. (1956) fed three levels of carotene; 0, 30, and 140 mg per head daily to three groups of bred Hereford heifers. The

liver vitamin A values varied directly with the amount of carotene fed. There was no significant difference in liver or plasma levels of vitamin A of calves at birth or at 56 days of age, regardless of the level of carotene intake of their dams during gestation.

All workers are not in agreement on liver storage in the newborn calf as affected by the carotene intake of the dam. Braun and Clark (1943) conducted an experiment in which cattle were exposed to Brucella Abortus, pregnant cows being separated into four dietary groups with different levels of vitamin A intake. The vitamin A content of the livers of 20 fetuses aborted by these cows was measured. At the same time, the vitamin A storage of a few dams in each dietary group was determined from liver samples obtained by partial hepatectomy immediately after abortion. It was found that the vitamin A content of the fetal liver, although low, was in direct relationship to the dam's diet. Baker et al. (1954) found that the liver stores of vitamin A and carotene of newborn calves from cows receiving 0 and 60 mg of carotene per head daily did not appear to be related to the treatment of the dam during gestation or her liver stores at parturition.

Spielman et al. (1946) fed Holstein and Guernsey heifers the following rations: wheat straw plus a concentrate mixture, hay plus corn silage and a normal "fitting" ration of concentrates. No significant differences were observed in the mean plasma carotene of the newborn calves from these dietary groups. However, when one million units of carotene were added daily to the normal "fitting" ration, the plasma vitamin A of the newborn calves was twice that of the unsupplemented groups. When one million units of vitamin A were added

to the "fitting" ration, the plasma vitamin A of the newborn calves showed a fourfold increase over the unsupplemented groups.

Kuhlman and Gallup (1940) reported that Jersey cows could reproduce normally when maintained for long periods of time on a carotene intake equivalent to 4.5 mg per 100 lb of body weight. Cows fed rations containing lower amounts of carotene, produced a smaller percentage of normal calves and had more trouble with retained placentas after calving. This report includes 31 gestation periods recorded from a herd of 17 Jersey cows. They (Kuhlman and Gallup, 1941) noted that the carotene requirement of Jersey cows was higher for reproduction than lactation and that the carotene requirement was higher during the early phase of lactation than during the latter phase. Kuhlman and Gallup (1942) concluded that the requirement for normal conception was apparently the same as the requirement for normal calving performance. In 21 cases where cows received the equivalent of 2.0 to 3.9 mg of carotene daily per 100 lb of body weight during the 90-day period preceding service, 1.99 services per conception were required. When the daily carotene intake was equivalent to 4.0 to 5.9 mg, 6.0 to 9.9 mg or 10.0 to 35.3 mg per 100 lb of body weight, the services per conception were 1.35, 1.15, and 1.23, respectively.

Ronning et al. (1953) summarized the results of an 8-year study of the carotene requirements of Guernsey cattle for reproduction. The results of 72 gestations indicate that an intake of the equivalent of 9.0 mg of carotene per 100 lb of body weight is necessary for successful reproduction. When the carotene intake was reduced below this

level, a relatively high incidence of retained placentas, abortions, blindness and weak calves resulted.

Converse and Meigs (1938) stated that for normal gestation cows should receive, during the last three months of gestation, 80 to 100 mg of carotene daily. When the daily carotene intake was as low as 60 mg per cow, there was a large percentage of dead calves dropped.

The recommended carotene allowance given by the National Research Council (1950) for wintering pregnant cows is 6.0 mg per 100 lb of body weight. This recommendation is based on the work reported by Davis and Madsen (1941) and Madsen and Davis (1949). The National Research Council recommends 6 mg per 100 lb "to provide for normal growth and reproduction and to build up and maintain a moderate storage of vitamin A". The National Research Council recommends that lactating cows receive 300 mg daily. Morrison's (1956) standards for gestation and lactation are 5.5 and 9.0 mg per 100 lb of body weight, respectively.

Byers et al. (1955) compared blood plasma, liver, and milk fat values for carotene and vitamin A in Jersey and Holstein cows on adequate and suboptimal carotene rations. Suboptimal rations fed during gestation and for long periods of time after birth resulted in low liver vitamin A and carotene values which failed to increase when supplements of carotene as high as 15 mg per 100 lb of body weight were added to the ration. Repeated injections of 250,000 or 1,250,000 I.U.* of vitamin A ester failed to result in any appreciable

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*One I.U. of vitamin A is equivalent to .6 mcg pure beta carotene.

increase in liver vitamin A or carotene in cows on suboptimal carotene rations. However, availability of injected vitamin A is questioned.

Hilton et al. (1944) concluded that 7500 I.U. of vitamin A daily was enough to promote growth in dairy heifers but the level should be increased to 30,000 I.U. to insure normal reproduction.

Sutton and Soldner (1945) made monthly determinations of carotene and vitamin A in the blood plasma of six mature cows and 16 bulls of each of the four major dairy breeds. The data showed a wide fluctuation in blood plasma carotene when the cattle were grazing green pasture. The blood plasma vitamin A varied over rather narrow limits in comparison to blood plasma carotene. Changes in blood plasma vitamin A did not closely follow blood plasma carotene, but tended to lag behind by about a month.

Rousseau et al. (1954) fed a vitamin A depletion ration at two nutritional levels of intake to 36 one-day-old dairy calves until the blood plasma vitamin A values decreased to less than 4 mcg per 100 ml. This resulted in 1 and 1.5 pounds average daily gain for the low and high levels of intake, respectively. Over-all plasma carotene and vitamin A were found to decrease but were not affected by the level of intake of the depletion ration.

Church et al. (1956) reported that cows on a high plane of nutrition depleted their vitamin A liver stores faster than cows on a low plane of nutrition. It was concluded that for the production of healthy calves by cows on low carotene rations, carotene intake should be 20 mg or more per 100 lb of body weight during subsequent lactation, regardless of plane of nutrition.

Wise et al.. (1948) found that feeding colostrum to one-day-old dairy calves at the rate of 1 lb per 10 lb of body weight daily caused a large increase in carotene and vitamin A in the blood of the newborn calf. Whole milk was fed to the calves at the same rate as the colostrum. However, even when produced by cows receiving high quality roughage, it did not provide sufficient vitamin A activity to prevent a continuous decline in the concentration of carotene and vitamin A in the blood to levels within or approaching the deficiency range. Rousseau et al. (1954) fed calves vitamin A depletion rations and rations meeting the minimum vitamin A requirements and compared plasma vitamin A and liver vitamin A. When plasma vitamin A and liver vitamin A values were expressed as logarithms, a positive linear relationship was found between these two variables.

Hauge et al. (1944) conducted experiments to determine the relative availability of carotene in dehydrated alfalfa hay as compared to carotene in oil as sources of vitamin A in rations for dairy cows. Two groups of cows were used in these experiments. Each group of cows was fed equal amounts of carotene at levels of 130, 200, and 300 mg per head daily. The results indicated that dairy cows can utilize carotene from alfalfa hay as readily as relatively pure carotene.

Boyer et al. (1942) in studies to determine blood plasma concentration and intake of carotene and vitamin A necessary for the growing calf, noted that plasma vitamin A was a more delicate measure of the state of nutrition than growth or plasma carotene. A blood plasma vitamin A level of 10 mcg per 100 ml was found to be necessary for adequate vitamin A nutrition of the calf, 7 to 8 mcg was borderline, and amounts less than this were considered to be inadequate.

Byers et al. (1956) studied the performance of dairy cattle on vitamin A deficient rations for three generations. They found that calves from vitamin A deficient dams showed severe damage of the pituitary, adrenal and sex glands at birth.

Jones et al. (1943) conducted 7 experiments over a 7-year period. They fed rations low in carotene to 310 head of feeder cattle ranging from 3 to 16 months of age at the time of being placed in the feedlot. The time required for depletion of body reserves of vitamin A, as indicated by night blindness, ranged from 45 to 268 days. Young animals became depleted in less time than older animals. A carotene level of 0.45 mg per 100 lb of body weight was not enough to maintain life during extended periods of feeding. Steers supplied this level after depletion fattened, but enough generalized edema was present to cause their carcasses to be condemned as food. A carotene level of 1.5 mg per 100 lb of body weight was not high enough to prevent night blindness. Slight liver storage of carotene and vitamin A occurred when the cattle received 2.5 to 3.0 mg of carotene daily per 100 lb of body weight.

Sherman et al. (1956) depleted Hereford steers of vitamin A by feeding ground corn cobs and a protein supplement. When the plasma vitamin A levels had declined below 10 mcg per 100 ml, the steers were dosed orally with different levels of vitamin A in oil, in aqueous emulsions, and in dry gelatin beadlets. The blood plasma vitamin A levels were determined every few hours after dosage. Liver biopsy samples were taken to measure vitamin A storage. In animals receiving vitamin A in aqueous solutions and in dry gelatin beadlets, substantial levels of vitamin A appeared in the blood within 12 hours

after administration. In animals fed the oil solutions of vitamin A there was a delay in the appearance of vitamin A in the blood.

Frey and Jensen (1946, 1947) stated that the rate of depletion of liver stores of carotene and vitamin A by beef steers decreases as the liver reserves are reduced. From a group of 140 yearling Hereford steers, 22 were slaughtered to estimate the initial liver stores of carotene and vitamin A. Ninety-eight of the steers were fed a high carotene maintenance ration, and slaughtered after 119 and 116 days of feeding. The remaining steers were subdivided into four groups and fed a fattening ration. They were slaughtered after 41, 76, 119, and 166 days of feeding. Although the steers fed the maintenance rations received 963 mg of carotene per head daily, their liver stores of carotene and vitamin A decreased during the 166-day feeding period. The liver reserves of carotene and vitamin A also decreased in the steers fed the fattening ration with a daily carotene intake of 309 mg. No symptoms of a vitamin A deficiency were observed during the study. The gains of the animals were satisfactory for the type of rations fed. When the liver stores of vitamin A of the steers fed the low carotene rations were plotted against time, the percentage drop in the liver reserves during each 40-day period was practically constant. These workers suggest that the rate of depletion of liver vitamin A stores of beef cattle is proportional to the total liver reserves.

Frey et al. (1947) studied the effect of vitamin A supplementation of a carotene-deficient ration on the performance of Hereford steer calves. One hundred and fourteen steers were divided into six lots of 19 steers each. The steers of Lot I were slaughtered at the

beginning of the experiment to establish initial stores of carotene and vitamin A. The rations for the remaining 5 lots of steers were supplemented as follows: Lot II, no supplement; Lot III, 25 I.U. vitamin A per lb of body weight daily; Lot IV, 100 I.U.; Lot V, 200 I.U. and Lot VI, 500 I.U. Nine steers from each lot were slaughtered after 166 days of feeding and the remaining 10 after 277 days. During the fourth month of the trial symptoms of vitamin A deficiency appeared in the steers of Lot II. After 277 days in the feedlot, 8 of the 10 remaining steers in Lot II showed symptoms of a vitamin A deficiency. Liver stores of vitamin A and carotene were almost completely depleted in the steers of Lot II after 166 days of feeding. The serum vitamin A content of the steers of Lot II dropped from an initial level of 30 mcg per 100 ml to 13.7 and 5.2 at 166 and 277 days, respectively. The serum values of the steers in Lot III remained near the initial level, but the liver reserves dropped from 47.1 to 17.4 mcg per gm while the plasma vitamin A increased from 39 to 48.9 mcg per 100 ml. Both serum and liver vitamin A values increased for the steers of Lots V and VI during the experiment. The steers of Lot II gained slower, and because of excess edema produced carcasses inferior to those of the other four lots.

Gallup et al. (1953) suggest that a species difference exists in the vitamin A response of cattle and sheep to phosphorus deficiency. Nine yearling steers, depleted in phosphorus and vitamin A reserves were fed 150 mg of carotene per head daily in rations supplying .5 and 3 gm of phosphorus daily. Plasma carotene levels were higher in the steers on the low-phosphorus ration. Plasma vitamin A values were lower in the phosphorus deficient steers and low vitamin A storage

in the liver was indicated. In a similar trial with lambs, results opposite to these were obtained. Church et al. (1954) demonstrated a species difference as to site of conversion of carotene to vitamin A. Intravenously administered carotene in aqueous solution was given vitamin A depleted calves and lambs which had been on a low vitamin A diet. It was found that lambs could convert the carotene thus administered, as indicated by a rise in plasma vitamin A levels, whereas calves showed no response. The authors suggested that such results might indicate that sheep possess extra-intestinal sites of conversion of carotene to vitamin A, a possible explanation for the low plasma carotene levels characteristic of this species.

Davis et al. (1956) demonstrated that the addition of choline or methionine to a calf ration caused an increase in blood plasma carotene but had no effect on the liver stores of carotene or vitamin A.

Murray and Campbell (1956) stated that aureomycin when added to rat rations had no effect on the absorption of vitamin A.

Erwin et al. (1956) concluded that neither aureomycin nor stilbestrol increased vitamin A storage in cattle. They also showed that the feeding of fat increased retention of carotene but not of vitamin A.

Rousseau et al. (1956) studied the effect of the following antioxidants, N, N^1 diphenyl-paraphenylenediamine, 6 ethoxy 2, 2, 4 trimethyl 1, 2 dihydroquinaline, and 2, 5 ditertiarybutylhydroquinone on the utilization of carotene. Holstein calves were fed a known amount of carotene from dehydrated alfalfa meal, with and without antioxidants. In every case, when the antioxidants were fed there was a greater utilization of carotene. Fat and vitamin E were also higher in the liver when the antioxidants were fed.

Mayfield and Roehm (1956) noted that vitamin B_{12} increased the liver storage of vitamin A in rats.

Worker (1956) demonstrated that the thyroid had no effect on the conversion of carotene to vitamin A.

Worker (1956) studied the effect of hepatectomy on the utilization of carotene. Rats and rabbits on a low plane of nutrition were either hepatectomized, hepatectomized and eviscerated, or left intact as controls. Carotene was given intravenously immediately following surgery and a control sample of blood was collected. A second sample was taken for vitamin A analyses 1-2 hours after the injection. Since the rat blood was available in such small quantities, samples from two or three rats were pooled for analysis. Conversion of carotene in the hepatectomized rats was as efficient as in the intact rats. The same was true for the hepatectomized and eviscerated rats within $\frac{1}{4}$ hour following injection.

PART 1. EFFECT OF THREE LEVELS OF CAROTENE SUPPLEMENTATION DURING LACTATION ON THE PERFORMANCE OF BEEF COWS AND THEIR CALVES

The carotene and vitamin A requirements of cattle are greatly influenced by their ability to accumulate large liver reserves of vitamin A during the lush grazing season. This may be sufficient to allow the mature animal to subsist for long periods of time on carotene deficient forage. Previous research at this station (Baker, 1953; Church, 1956) has shown that deficiency symptoms can develop in young suckling calves even though their dams appear normal. It has been noted that carotene supplementation of the dams during gestation is not necessary unless they have been off green feed for long periods of time prior to calving.

This experiment was designed to study the effect of feeding different levels of carotene to beef cows during the first 3 months of lactation on the vitamin A nutrition of the cows and their calves.

Experimental

Twenty-one bred, two-year-old Hereford heifers were selected from the experiment station herd, moved to small dirt pens and started on experiment in December, 1955. These heifers had grazed good native grass pasture the previous summer and fall. During the last 6 months of gestation, they were fed (free choice) weathered, range-

grass hay cut in December and devoid of carotene, plus 2½ lb of cottonseed meal and 2 lb of cracked milo per head daily. During lactation the cows were continued on the winter-cut hay (free choice) and received 5 lb of cracked milo and 3 lb of cottonseed meal per head daily. The cattle had access to a mineral mixture of 2 parts salt and 1 part steamed bone meal at all times. These rations were calculated to meet the recommended allowances of the National Research Council for all essential nutrients, with the exception of carotene. The calves had access to a mixture of oats, milo, and cottonseed meal in a creep feeder.

At the time the cows were moved to drylot, blood samples were taken. Further samples were taken from the cows and calves at parturition and monthly thereafter to three months post-partum. These were centrifuged, the plasma removed and stored in a frozen state. When sufficient samples had been collected, carotene and vitamin A determinations were made using the method of Kimble (1939).

Liver samples were taken at the beginning of the experiment, at parturition and at three months post-partum for the cows, and at three months of age for the calves. In obtaining the samples, the cow was restrained in a squeeze chute by means of a head gate. An area, approximately 4 inches square was clipped over the 12th and 13th ribs about 10 inches from the midline of the backbone. This area was anesthetized with 30 ml of 4 percent procaine hydrochloride solution. After about 20 minutes an incision approximately 2 inches long was made in the area between the 12th and 13th rib. A trocar and canula (1 inch in diameter and 6 inches long) was inserted into the incision. The liver surface was located with the aid of a flash-

light and the trocar was removed. A core of liver tissue weighing 1 to 2.5 gm was removed with a special instrument. The liver sample was wrapped in tinfoil, placed in a small vial and stored in a deep-freeze. Details of this technique have been reported by Van Arsdell (1952) and Whitehair et al. (1952). Liver samples were analyzed according to the method of Gallup and Hoefer (1946).

The cows were alloted to treatment according to calving order; first cow to Lot I, second to Lot II, third to Lot III, etc. This procedure was followed in alloting all cows. Following parturition, the cows of Lots I, II, and III received 10, 20, and 30 mg of carotene per 100 lb of body weight, respectively.

The carotene used in this experiment was a carrot oil concentrate in soybean oil.* It was stored in an airtight metal drum. The carotene allowance for each cow was weighed individually, mixed with the cottonseed meal, and fed immediately. The cows were fed their respective carotene supplement in cottonseed meal individually every third day, starting at parturition. Care was exercised to avoid consumption of the concentrate by the calves. Frequent samples of the carrot oil were analyzed for carotene, and the daily allowance adjusted accordingly.

Close observations were made on the cows and calves throughout the experiment, and a record was maintained on incidence of scours or any other abnormalities.

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*The carrot oil concentrate was generously supplied by Nutritional Research Associates, Inc., South Whitley, Ind.

The cows and calves were removed from the experiment when the calves reached 3 months of age. Data were obtained on body weights of cows and calves at parturition and at monthly intervals thereafter.

Results and Discussion

The average liver levels of vitamin A and carotene for the three lots of cows and calves are presented in Table I. Plasma levels of vitamin A and carotene are shown in Table II, while changes in body weights of the cows and their calves are presented in Table III. Similar data for individual animals are presented in Appendix Tables I, II, III, and IV.

TABLE I

Mean Vitamin A and Carotene Contents of Livers of Beef Cows and Their Calves (mcg/gm dry matter)*

	Lot No.	6 mo. Prepartum	Partu-rition	3 mo. Post-partum
Cows				
Liver vitamin A	1	311.5	27.1	20.5 ± 13.73
	2	293.1	26.2	31.5 ± 11.58
	3	225.9	21.7	35.3 ± 15.98
Liver carotene	1	18.9	5.2	9.9 ± 3.56
	2	15.4	5.6	12.4 ± 2.70
	3	15.6	4.7	21.7 ± 8.59
Calves				
Liver vitamin A	1			2.58 ± 1.16
	2			3.66 ± 1.52
	3			5.20 ± 2.57
Liver carotene	1			1.49 ± .47
	2			2.26 ± .77
	3			2.17 ± 1.05

*All data collected on dams of calves that died during the experiment were ommitted.

Examination of the carotene and vitamin A levels at the beginning of the experiment show that the liver stores of vitamin A and carotene were high in the young heifers which had been grazing green pasture during the summer months. There was a rapid depletion of both vitamin A and carotene when they were placed on rations practically devoid of carotene. At parturition, 6 months later, the liver vitamin A had declined to approximately 9 percent of the original level, while the carotene had been reduced to approximately 30 percent.

As shown in Table I, supplementing the ration with 10 mg of carotene per 100 lb of body weight during lactation (Lot I) did not maintain the liver vitamin A stores of the cows. Feeding 20 or 30 mg per 100 lb body weight (Lots II and III) resulted in a slight increase in liver storage of vitamin A. Baker et al. (1954) and Church et al. (1956), state that cows on a low carotene ration during the latter half of gestation require a daily carotene intake of 20 mg or more per 100 lb body weight during subsequent lactation in order to produce healthy calves. The analysis of variance of liver and plasma carotene and vitamin A failed to indicate a significant difference among the lots. Individual variation within lots, as indicated by the standard deviations, accounts for this lack of significance. This similar variation has been reported by Van Arsdell (1952), Baker (1954), and Church (1956).

Liver vitamin A and carotene values in the calves were extremely low at 3 months of age, but tended to reflect the carotene intakes of their dams.

TABLE II

Mean Vitamin A and Carotene Contents of Plasma of Beef Cows and Their Calves* (mcg per 100 ml)

	Lot No.	5 mo. Prepartum	Parturition	Lactation 1 mo.	Lactation 2 mo.	Lactation 3 mo.
			COWS			
Plasma Vitamin A						
	1	35.8	10.3	12.5	15.7	20.8 ± 6.53
	2	34.4	9.2	14.4	20.7	23.2 ± 7.15
	3	34.9	7.1	20.9	24.0	26.8 ± 10.32
Plasma Carotene						
	1	111.9	27.1	134.4	144.5	193.9 ± 79.7
	2	112.8	29.2	246.5	256.4	267.2 ± 36.5
	3	102.5	30.6	287.1	334.1	292.1 ± 115.5
			CALVES			
Plasma Vitamin A						
	1		4.52	6.7	4.6	5.5 ± 4.57
	2		4.42	4.5	6.12	8.95 ± 4.65
	3		4.5	7.2	7.9	8.3 ± 7.80
Plasma Carotene						
	1		6.5	19.4	24.0	33.5 ± 19.6
	2		10.3	22.9	25.2	34.8 ± 22.9
	3		6.5	25.6	25.4	33.1 ± 15.3

*All data on calves that died were omitted. All data collected on dams of calves that died were omitted.

Initial plasma vitamin A and carotene values (Table II) could be considered normal. By the end of gestation, all animals showed a decline to values that according to Madsen and Davis (1949) are indicative of a low plane of vitamin A nutrition. These workers reported that reproduction in cows was poor when plasma vitamin A dropped below 18 mcg per 100 ml, at or near parturition. Payne and Kingman (1947) found that blood carotene levels of approximately 118 mcg per 100 ml were necessary for normal reproduction and lactation in beef heifers.

When carotene was fed after parturition, the plasma carotene values increased rapidly while plasma vitamin A increased at a much slower rate. In Lot I, plasma vitamin A values did not reach the "normal" level until the third month of lactation. This is in general agreement with Sutton and Soldner (1945) who found that changes in plasma vitamin A tended to lag about a month behind changes in plasma carotene.

The plasma vitamin A and carotene values of the calves were very low at birth. They showed a slight increase to 3 months of age but were still extremely low when they were removed from the experiment. The plasma levels of the calves did not reflect the supplemental level of carotene fed to their dams. This is in agreement with Baker (1954) and Church (1956).

All of the calves were born alive in this experiment but most of them were weak at birth and very susceptible to scours during the first few weeks. Diarrhea was very noticeable throughout the trial in calves of Lots I and II whose dams received 10 and 20 mg of carotene daily per 100 lb of body weight. Sixteen individual

cases of calf scours were treated with antibiotics in Lot I, 12 in Lot II, and 3 in Lot III during the three-month period.

Two calves were lost in Lot I and one in Lot II. Severe diarrhea was noted in these calves shortly before death. Postmortum examinations were made by the Pathology Department of the School of Veterinary Medicine. The liver of one calf contained circumscribed depressions 1 mm in diameter to 3/4 inch in diameter, and chronic nephritis was noted in both kidneys. This calf went into convulsions about one hour before death. In another calf, a 3x2 cm ulcer was found in the mucosa of the abomasum. Raised, greyish nodules up to 2 mm in diameter were found throughout duodenum and extended halfway through jejunum. There was slight catarrhal enteritis in the remainder of the intestinal tract with small areas of congestion and hemorrhage in terminal colon. The liver of this calf was slightly pale. In the third calf, a few small areas of focal interstitial nephritis were noted in one kidney, and small areas of lobular pneumonia were scattered in the opical and diaphragmatic lobes of both lungs. From these postmortem findings it was not possible to definitely establish the cause of death, although certain of the symptoms could be attributed to a vitamin A deficiency.

The cows were maintained in good thrifty condition throughout the experiment. The rations fed were sufficient to produce an increase in weight from parturition to 3 months postpartum (see Table III). No differences were noted in the general health or thriftiness of the three lots of cows. The calf weights were lower than would be expected under good range conditions. The weight gains of the calves to three months, however, does not present a true picture

TABLE III

Mean Weight Changes of Cows During Gestation and Lactation and Weight Changes of Their Calves (lb)

Lot No.	6 mo. Prepartum	Parturition	Loss to parturition	1 mo. Postpartum	2 mo. Postpartum	3 mo. Postpartum	Gain During Lactation
				Cows			
1	712	662	50	687	721	734	47
2	755	731	24	738	758	795	57
3	726	694	32	706	735	775	69
				Calves			
1		59		94	130	160	107
2		59		90	119	151	92
3		58		83	118	148	90

because the lightest calves were lost out of Lots I and II, tending to make their mean weight higher at the end of the experiment. However, there were no significant differences in the weights of cows and calves among the three groups. The calves of Lots I and II had an unthrifty appearance during the latter two months of the experiment. No gross outward symptoms of vitamin A deficiency were noted among the cows or calves at any time during the experiment, with the exception of frequent scouring among the calves.

SUMMARY

Beef cows, after depletion of body stores of vitamin A and carotene during the last 6 months of gestation were fed supplemental carotene to supply 10, 20, and 30 mg per 100 lb of body weight for

the first three months of lactation. No deficiency symptoms appeared in the cows. The different levels of carotene intake during early lactation had no consistent effect on calf weights at three months. There were no significant differences among the cows or calves in blood and liver vitamin A and carotene levels. Death loss was highest in calves nursing dams receiving 10 mg of carotene per 100 lbs during early lactation.

It appears that beef cows after depletion in vitamin A must receive relatively large amounts in the feed in order to protect their calves against a deficiency. Individual variation among cows in blood and liver carotene and vitamin A values is large. Under range conditions, it may be more profitable to administer carotene or vitamin A directly to the calves (i.e., in the creep feed) than to feed high levels of supplemental carotene to their dams.

PART II. ALFALFA HAY AND DEHYDRATED ALFALFA MEAL AS DIETARY SOURCES OF CAROTENE FOR FATTENING STEER CALVES

Alfalfa hay and dehydrated alfalfa meal have been used extensively in steer fattening rations to supply protein, minerals, and carotene. In many steer fattening rations, alfalfa hay or dehydrated alfalfa meal comprise the sole protein and carotene supplement.

This experiment was designed to determine the amounts of alfalfa hay and dehydrated alfalfa meal required in low carotene rations to insure adequate vitamin A nutrition of fattening steer calves fed in drylot for approximately 166 days.

Experimental

Sixty choice, Hereford steer calves were selected from the experimental herd and from a group purchased from a ranch in western Oklahoma. They were given about a month to recover from weaning and shipment and to become accustomed to the change in feed and quarters. During this time they were drenched with phenothiazine to control internal parasites.

The calves were divided into 6 lots of 10 calves each on the basis of source, body weight and feeder grade. They were full-fed rolled milo, with limited amounts of sorghum silage and the following protein supplements per head daily:

Lot I. 1.8 lb of cottonseed meal.

Lot II. 1.2 lb of cottonseed meal plus .9 lb of dehydrated alfalfa meal pellets.

Lot III. 1.2 lb of cottonseed meal plus .95 lb of alfalfa hay.

Lot IV. 0.8 lb of cottonseed meal plus 1.8 lb of dehydrated alfalfa meal pellets.

Lot V. 0.8 lb of cottonseed meal plus 1.9 lb of alfalfa hay.

Lot VI. 3.6 lb of dehydrated alfalfa meal pellets.

In Lots II, V, and VI, dehydrated alfalfa meal pellets replaced $\frac{1}{4}$, $\frac{1}{2}$, and all of the cottonseed meal on a protein-equal basis. In Lots III and IV alfalfa hay replaced $\frac{1}{4}$ and $\frac{1}{2}$ of the cottonseed meal on a protein-equal basis.

The calves were started on 2.5 lb of rolled milo per head daily and gradually worked up to a full-feed. Sorghum silage was reduced from an initial level of 14 lb per head daily to 8 to 9 lb at the end of the trial. The cattle were fed twice daily. A mineral mixture of 2 parts salt and 1 part steamed bone meal was available to all steers at all times.

Blood samples were taken at the beginning of the experiment, midway through the feeding period and at the end of the experiment (166 days). These samples were centrifuged and the plasma stored in tightly stoppered test tubes in a deepfreeze. They were analyzed at a later date for vitamin A and carotene according to the method of Kimble (1939). Liver samples were taken when the steers were slaughtered, approximately a week after the final blood samples were taken. These samples were wrapped in tinfoil, placed in stoppered

vials and stored in the deepfreeze. Liver samples were analyzed at a later date by the method of Gallup and Hoefer (1946).

All feeds were sampled and analyzed three times during the trial. Weight gains, average daily rations fed and feed required per cwt. gain are shown in Appendix Table V; the chemical composition of feeds is shown in Appendix Table VI.

Results and Discussion

The carotene intake and average daily gains of the calves are summarized in Table IV. The blood and liver data are summarized in Table V. Similar data for the individual steers are presented in Appendix Table VII.

TABLE IV

Carotene Intakes and Average Daily Gains of Steers Fed Varying Amounts of Dehydrated Alfalfa Meal Pellets and Alfalfa Hay as Replacements for Cottonseed Meal

Lot No.	Source of Carotene*	Estimated Daily Carotene Intake per head	Carotene Intake per cwt.		Average Daily Gain
			Initial	Final	
		(mg)	(mg)	(mg)	(lb)
1	Basal	20.2	4.0	2.4	2.10
2	Dehydrated alfalfa pellets	49.6	9.6	5.6	2.18
3	Alfalfa hay	42.0	8.1	4.9	2.05
4	Dehydrated alfalfa pellets	79.4	15.1	8.9	2.18
5	Alfalfa hay	62.3	12.0	7.1	2.16
6	Dehydrated alfalfa pellets	124.4	23.7	14.4	2.05

*In addition, all lots were fed sorghum silage.

TABLE V

Mean Plasma and Liver Carotene and Vitamin A and Average Daily Gains of Steers

Lot No.	Source of Carotene	Blood Plasma (mcg %)						Liver (mcg/gm D.M.)		Average daily gain (lbs)
		November		January		April				
		Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	
1	Basal	110.7	28.7	80.8	29.81	47.6 ± 13.17	15.0 ± 4.52	5.3 ± 2.08	2.8 ± 1.95	2.10 ± 0.26
2	Dehydrated alfalfa pellets	169.1	32.7	102.3	34.4	82.8 ± 17.55	24.2 ± 4.28	6.4 ± 2.07	7.1 ± 5.96	2.18 ± 0.22
3	Alfalfa hay	186.9	35.1	88.7	29.6	71.0 ± 21.06	22.8 ± 3.73	6.6 ± 1.94	5.8 ± 3.76	2.05 ± 0.32
4	Dehydrated alfalfa pellets	196.8	35.2	98.6	33.0	82.5 ± 33.08	24.6 ± 7.66	6.6 ± 2.06	14.2 ± 8.22	2.18 ± 0.29
5	Alfalfa hay	152.9	33.6	103.7	34.9	77.3 ± 32.67	24.8 ± 6.75	6.3 ± 2.44	6.2 ± 4.07	2.16 ± 0.25
6	Dehydrated alfalfa pellets	123.9	30.0	116.0	31.6	95.0 ± 37.90	26.7 ± 6.91	8.5 ± 3.35	12.0 ± 11.15	2.05 ± 0.22

None of the steers in this experiment showed any symptoms of a vitamin A deficiency, although some watering of the eyes, stiffness and swelling of the forelimbs were observed in the basal group as the calves were being sold in the Oklahoma City yards.

The levels of carotene intake were not reflected in the average daily gains of the six lots of steers. Differences in average daily gains among the lots were not statistically significant. Jones et al. (1943) reported that although cattle fattened on vitamin A deficient rations, a large percentage of the carcasses were condemned due to edema.

Examination of the blood data indicates that the basal ration composed of milo, cottonseed meal and sorghum silage did not maintain the steers in an adequate state of vitamin A nutrition during the fattening period of 166 days. However, this was not reflected in average daily gain. Church (1956) reported a mean plasma vitamin A level of 7.7 mcg per 100 ml for steers that were fed a basal ration similar to the one fed in this experiment. The low carotene intake in the work reported by Church (1956) was reflected in the average daily gain. Several steers in the basal lot developed night blindness and, due to edema, some of the carcasses were condemned. The estimated daily carotene intake in the experiment reported by Church was 12.1 mg as compared to 20.2 mg in this current experiment. Further examination of the blood data indicates that the steers on the basal ration were bordering on a vitamin A deficiency at the end of the experiment. Frey et al. (1947) observed vitamin A deficiency symptoms in steers when their plasma vitamin A values declined below 13.7 mcg per 100 ml. It should be kept in mind that the feeding

period in this experiment (166 days) was shorter than that normally employed in other areas. Had the experiment been continued for a longer period of time it seems possible that the steers on the basal ration would have developed vitamin A deficiency symptoms before slaughter. Statistical analysis showed that there was a highly significant difference ($P < .01$) among the groups in plasma vitamin A and a significant difference ($P < 0.05$) in plasma carotene.

No information is available concerning initial liver stores; however, Jones et al. (1943) found that slight storage occurred when steers were fed carotene at levels of about 15 mg per head (2.5 to 3.0 mg per 100 lb of body weight).

The liver carotene and vitamin A values of the steers in all lots were low at the end of the trial and extremely low in the basal lot. Frey et al. (1949) observed that symptoms of a vitamin A deficiency developed in steers when liver vitamin A values declined below 1.4 mcg per gram of dry liver. In view of their findings it seems logical that the low liver vitamin A values of the steers of the basal lot indicate that they were bordering on a vitamin A deficiency. These observations are in agreement with those of Church (1956). Difference in liver vitamin A values among the six lots were statistically significant at the .01 level of probability whereas liver carotene values were not.

The data obtained indicate that an average daily carotene intake of 20.2 mg was sufficient to support growth and fattening in weanling steer calves fed 166 days in drylot. Morrison (1956) recommends that 500-lb steer calves receive 25 mg of carotene per head daily while 900-lb calves that are being fattened receive 50 mg per head daily.

The nutrient allowance of carotene as recommended by the National Research Council (1950) is 2 mg of carotene per lb of dry matter. This amount is in fairly close agreement with that recommended by Morrison but considerably lower than the amount supplied in the basal ration of the present study.

The calves fed dehydrated alfalfa pellets as compared to those fed hay had slightly higher amounts of carotene and vitamin A in the blood and liver; however, this was to be expected since their carotene intake was higher.

SUMMARY

Six lots of steer calves fed a basal ration of milo, cottonseed meal and sorghum silage were used to compare the value of dehydrated alfalfa meal pellets and alfalfa hay as a source of carotene.

The substitution of approximately one lb dehydrated alfalfa meal pellets for cottonseed meal in the basal ration (½ replacement of cottonseed meal) resulted in a slight increase in average daily gain. The substitution of alfalfa hay or dehydrated alfalfa meal pellets at levels higher than one lb did not appear to be beneficial in further increasing weight gains. Substituting alfalfa hay or dehydrated alfalfa meal pellets for cottonseed meal in the basal ration increased carotene and vitamin A plasma and liver levels. Such substitution of alfalfa hay or dehydrated alfalfa meal pellets in the basal ration in this trial did not appear to be necessary to prevent vitamin A deficiency symptoms. It appears that a daily carotene intake of approximately 20 mg for weanling calves fed 166 days in drylot is ample to support satisfactory gains.

PART III. RELATIONSHIP OF PLASMA VITAMIN A AND CAROTENE TO LIVER VITAMIN A IN BEEF CATTLE

Plasma levels of vitamin A and carotene are commonly used as measures of vitamin A nutrition. From the data collected it has been observed that plasma carotene varies over a wide range depending upon the dietary intake of the animal. Plasma and liver vitamin A values vary over a somewhat narrower range. It seems possible that the amount of vitamin A stored in the liver may be the best measure of the amount of carotene that must be added to the ration to support adequate vitamin A nutrition in beef cattle. Yet the liver biopsy technique as practiced at this station is laborious and of some danger to the animal. Therefore, if plasma vitamin A or carotene levels could be shown to reflect liver stores, the more difficult biopsy procedure could be avoided.

Extensive data on vitamin A in pregnant cows, suckling calves and fattening steers have been collected at this station over the past four years. Using these data, an attempt has been made to ascertain to what extent vitamin A liver stores are reflected by the plasma vitamin A and carotene levels.

There is little information on the individual variability of plasma vitamin A levels. Should there be a tendency for certain cows to maintain higher plasma vitamin A levels than others, this

observation would be of importance in allotting cattle to experimental treatment. A test was made using available data on cows, calves and steers in order to study the repeatability of vitamin A values.

Experimental

Analysis was made of available data on plasma vitamin A and carotene, and liver vitamin A of beef cows at six months prepartum and at parturition. The data were obtained from research conducted by Baker (1953) and Church (1956) together with that reported in Part I of this study. Included in the data were the results of blood and liver analysis from 56 cows that received rations devoid of carotene during the last 6 months of gestation. The data were accumulated over a three-year period. Data on blood and liver of the calves from these cows at 3 months of age were also included in this study.

Other data were from 176 steers fattened in drylot. The data included the results reported by Church (1956), and the results reported in Part II of this current study. In the present studies, blood samples were taken at the termination of the experiment from steers that had been fed a fattening ration for a period of approximately 165 days. Liver samples were obtained at slaughter.

Individual variation among cows and steers during one experiment was studied by ranking the animals within each lot at each bleeding according to their plasma vitamin A values. Repeatability estimates were also conducted using the method of Snedecor (1946).

Results and Discussion

The correlation coefficients are presented in Table VI.

Results of this study indicate that plasma and liver levels of vitamin A show little correlation when liver stores are extremely high. A highly significant ($P < .01$) correlation was found in samples of blood and liver taken from cows at parturition when the average plasma vitamin A level was 12.68 mcg per 100 ml and the liver vitamin A 56.29 mcg per gm of dry matter. A highly significant ($P < .01$) correlation was found between vitamin A samples of blood and liver of fattening steers when the average levels were 21.98 mcg per 100 ml for plasma and 4.95 mcg per gm of dry matter for liver. A significant correlation ($P < .05$) was found between blood and liver samples of steers when the average vitamin A values were 28.23 mcg per 100 ml for plasma and 10.6 mcg per gm of dry matter for liver. There was a significant correlation ($P < .05$) between plasma and liver samples of calves when the average vitamin A values were 8.1 mcg per 100 ml for plasma and 4.9 mcg per gm of dry matter for liver.

The statistical analysis showed a highly significant ($P < .01$) correlation between plasma carotene and liver vitamin A in the initial samples taken at 6 months prepartum from cows that had grazed native grass pasture during the previous summer and early fall. The mean vitamin A values were 121.5 mcg per 100 ml for plasma and 290.8 mcg per gm of dry matter for liver. There was a significant ($P < .05$) correlation between plasma carotene and liver vitamin A in steers that received approximately 3 lb of dehydrated alfalfa

TABLE VI

Relationship of Plasma Vitamin A and Carotene to Liver Vitamin A in Cows, Calves and Steers

Treatment	No. of Animals	Mean plasma vitamin A value (mcg/100 ml)	Mean plasma Carotene value (mcg/100 mo)	Mean liver vitamin A value (mcg/gm dry matter)	Correlation coefficient of liver vitamin A with: Plasma Vitamin A	Correlation coefficient of liver vitamin A with: Plasma Carotene
Cows						
Grazing good pasture during summer and early fall	56	33.6	121.5	290.8	.0383	.6087**
Fed low carotene rations in drylot (parturition samples after 6 mo. in drylot)	55	12.7	24.4	56.3	.5123**	-.2188
Calves						
Nursing dams in drylot	48	8.1	20.7	4.9	.3398*	-.0180
Steers						
Basal ration[1]	30	15.7	43.4	2.3	.1627	.3121
Basal plus 1.2 lb alfalfa hay daily	29	23.9	70.0	4.3	.1463	.2190
Basal plus .8 lb dehydrated alfalfa meal pellets daily	29	21.9	70.2	4.9	.4640*	.1565
Basal plus 2.4 lb alfalfa hay daily	30	26.4	78.1	6.1	-.0178	-.0640
Basal plus 1.6 lb dehydrated alfalfa meal pellets daily	30	25.1	87.7	9.2	.3221	.3392
Basal plus 3.2 lb dehydrated alfalfa meal pellets daily	28	28.2	124.5	10.6	.3930*	.3793*

*Significant at 5% level of probability.
**Significant at 1% level of probability.
[1]Basal ration consisted of cottonseed meal, sorghum silage and milo.

meal pellets daily. The mean plasma carotene and liver vitamin A values were 124.5 mcg per 100 ml for carotene and 10.6 mcg per gram of dry matter for liver. These results indicate that plasma carotene and liver vitamin A may be correlated when the carotene intake has been high over an extended period of time.

When analysis was made of the repeatability of plasma vitamin A values of individual cows and steers during one trial, no definite pattern could be established. Individuals having the highest initial plasma vitamin A values did not necessarily maintain this relationship throughout the experiment; in some cases they had the lowest values at subsequent bleedings. The intra-lot correlations between vitamin A blood values of the same individual were -0.1596 for cows and 0.0578 for steers.

Summary

Analysis was made of available data on plasma vitamin A and carotene and liver vitamin A of samples taken from beef cows 6 months prepartum and at parturition over a three-year period. Analysis was also made on samples taken from calves produced by cows fed varying levels of carotene during lactation, and on samples from steers fed fattening rations for approximately 165 days.

Results of this study indicate that plasma and liver vitamin A are correlated only when the plasma vitamin A levels are low. Plasma carotene and liver vitamin A values were correlated only when plasma carotene values were high possibly due to an extended period of high-carotene intake prior to sampling. Repeatability estimates indicated no tendency for individual cattle to maintain high or low plasma vitamin A levels.

LITERATURE CITED

Baker, F. H. 1953. Studies of the vitamin A and carotene nutrition of beef cattle. Ph.D Thesis. Okla. Agri. and Mech. Col., Stillwater, Oklahoma.

Baker, F. H., L. S. Pope and Robert MacVicar. 1954. The effect of vitamin A stores and carotene intake of beef cows on the vitamin A content of the liver and plasma of their calves. J. Animal Sci. 13:802.

Boyer, P. O., P. H. Phillips, N. S. Lundquist, C. W. Jensen and I. W. Rupel. 1942. Vitamin A and carotene requirements for the maintenance of adequate blood plasma vitamin A in the dairy calf. J. Dairy Sci. 25:433.

Braun, Werner and B. N. Carle. 1943. The effect of diet on the vitamin A content of the bovine fetal liver. J. Nutr. 26:549.

Byers, J. H., P. H. Weswig, J. F. Bone and I. R. Jones. 1955. Carotene in the ration of dairy cattle. I. The influence of long periods of suboptimal carotene intake on the carotene and vitamin A values of the blood, liver and milk fat of dairy cows. J. Dairy Sci. 38:657.

Byers, J. H., I. R. Jones and J. F. Bone. 1956. The influence of suboptimal levels of carotene intake upon the microscopic aspect of selected organs. J. Dairy Sci. 39:1556.

Church, D. C. 1956. Vitamin A studies with beef cattle. Ph.D Thesis. Okla. Agri. and Mech. Col., Stillwater, Okla.

Church, D. C., Robert MacVicar, J. G. Bieri, F. H. Baker and L. S. Pope. 1954. Utilization of intravenously-administered carotene by sheep and cattle. J. Animal Sci. 13:677.

Church, D. C., L. S. Pope and Robert MacVicar. 1956. Effect of plane of nutrition of beef cows on depletion of liver vitamin A during gestation and on carotene requirements during lactation. J. Animal Sci. 15:1078.

Converse, H. T. and E. B. Meigs. 1938. Carotene requirements for normal reproduction. J. Dairy Sci. 21:114.

Davis, C. L., R. F. Elliott and C. A. Lassiter. 1956. The effect of lecithin, choline and methionine on the vitamin A and carotene plasma and liver stores of young dairy calves. J. Dairy Sci. 39:440.

Davis, Russell E. and L. L. Madsen. 1941. Carotene and vitamin A in cattle blood plasma with observations on reproductive performance at restricted levels of carotene intake. J. Nutr. 21:135.

Erwin, E. S., I. A. Dyer and M. E. Ensminger. 1956. The influence of fat, chlorotetracyline and stilbestrol on vitamin A and carotene storage in the liver of beef steers. J. Animal Sci. 15:1147.

Frey, P. R. and R. Jensen. 1946. Depletion of hepatic reserves of carotene and vitamin A in cattle. J. Nutr. 32:133.

Frey, P. R., R. Jensen and W. E. Connell. 1947. Vitamin A intake in cattle in relation to hepatic stores and blood levels. J. Nutr. 31:421.

Frey, P. R. and R. Jensen. 1947. Depletion of vitamin A reserves in the livers of cattle. Science 105:313.

Gallup, W. D. and J. A. Hoefer. 1946. Determination of vitamin A in liver. 2nd Eng. Chem., Anal. Ed. 18:288.

Gallup, Willis D., O. O. Thomas, O. Burr Ross and C. K. Whitehair. 1953. Carotene and vitamin A metabolism in cattle and sheep on phosphorus-deficient rations. J. Animal Sci. 12:715.

Guilbert, H. R. and G. H. Hart. 1935. Minimum vitamin A requirements with particular reference to cattle. J. Nutr. 10:409.

Hart, G. H. and H. R. Guilbert. 1933. Vitamin A deficiency as related to reproduction in range cattle. Calif. Exp. Sta. Bul. 560:1.

Hauge, S. M., R. J. Westfall, J. W. Wilbur and J. H. Hilton. 1944. The vitamin A requirements of dairy cows for production of butterfat of high vitamin A value. III. Availability of carotene in dehydrated alfalfa hay as compared with carotene in oil. J. Dairy Sci. 27:63.

Hilton, J. H., J. W. Wilbur and S. M. Hange. 1944. Vitamin A requirements of dairy cattle for normal growth and reproduction. J. Dairy Sci. 27:631.

Jones, J. H., H. Schmidt, R. E. Dickson, G. S. Fraps, J. M. Jones, J. K. Riggs, A. R. Kemmerer, P. E. Howe, W. H. Black, N. R. Ellis and Paul T. Marion. 1943. Vitamin A studies in fattening feeder calves and yearlings. Tex. Agr. Exp. Sta. Bul. 630:1-50.

Kimble, M. S. 1939. The photocolorimetric determination of vitamin A and carotene in human plasma. J. Lab. Clin. Med. 24:1055.

Kuhlman, A. H. and W. D. Gallup. 1940. Carotene (provitamin A) requirements of dairy cattle for reproduction. Amer. Soc. Ani. Prod. Proc. 67-73.

Kuhlman, A. H. and W. D. Gallup. 1941. Carotene (provitamin A) requirements of dairy cattle for lactation. J. Dairy Sci. 24:522.

Kuhlman, A. H. and W. D. Gallup. 1942. Carotene requirements for dairy cattle for conception. J. Dairy Sci. 25:688.

Madsen, L. L. and R. E. Davis. 1949. Carotene requirements for beef cattle for reproduction. J. Animal Sci. 8:625.

Mayfield, H. R. and Richard R. Roehm. 1956. Carotene utilization as influenced by the addition of vitamin B_{12} to diets containing yeast as a synthetic vitamin mixture. J. Nutr. 58:483.

Morrison, Frank B. 1956. Feeds and feeding. 22nd Ed. Morrison Pub. Co., Ithaca, N. Y.

Murray, T. K. and J. A. Campbell. 1956. Further studies on the effect of aureomycin on the apparent utilization of vitamin A by the rat. J. Nutr. 59:319.

National Research Council. 1950. Recommended nutrient allowances for beef cattle. Washington, D. C.

Payne, M. G. and H. E. Kingman. 1947. Carotene blood levels and reproductive performance in range Hereford cattle. J. Animal Sci. 6:50.

Roberts, W. K., I. A. Dyer and M. E. Ensminger. 1956. Hepatic and plasma levels of vitamin A in gestating-lactating heifers as affected by various levels of carotene intake. J. Animal Sci. 15:1263.

Ronning, Magnar, E. R. Berousek, A. H. Kuhlman and Willis D. Gallup. 1953. The carotene requirements for reproduction in Guernsey cattle. J. Dairy Sci. 36:52.

Rousseau, J. E., C. M. Dembiczak, K. L. Dolge, H. D. Eaton, G. Beall and L. A. Moore. 1954. Relationships between plasma vitamin A and liver vitamin A in calves fed a vitamin A depletion ration and calves fed minimum levels of vitamin A or carotene. J. Dairy Sci. 37:1376.

Rousseau, J. E., C. F. Helmboldt, C. M. Dembiczak, E. L. Jungherr, H. D. Eaton and G. Beall. 1954. Effect of two levels of intake of a vitamin A depletion ration on some blood constituents and deficiency criteria in the dairy calf. J. Dairy Sci. 37:857.

Rousseau, J. E., H. D. Eaton, R. Teichman, C. F. Helmboldt, E. L. Jungherr, E. E. Bacon and K. L. Dolge. 1956. Effect of some antioxidants on the utilization of carotene by Holstein calves. J. Dairy Sci. 39:1671.

Semb, J., C. A. Baumann and H. Stienbach. 1934. The carotene and vitamin A content of colostrum. J. Biol. Chem. 107:697.

Sherman, W. C., W. M. Reynolds, G. O. Kuhn, C. K. Whitehair and H. G. Luther. 1956. Utilization of different forms of vitamin A by beef cattle. J. Animal Sci. 15:1242.

Spielman, A. A., J. W. Thomas and J. K. Loosli. 1946. The placental transmission and fetal storage of vitamin A and carotene in the bovine. J. Dairy Sci. 29:516.

Sutton, T. S. and P. A. Soldner. 1945. Seasonal variation in the blood plasma carotene and vitamin A of adult dairy cattle. J. Dairy Sci. 859.

Van Arsdell, W. J. 1952. A study of systems of management and protein supplements for range Hereford cows and the effect of each upon certain blood constituents of the cows and their calves. II. A liver biopsy technique and observations of its use in vitamin A studies with beef cattle. Ph.D Thesis. Okla. Agr. and Mech. Col., Stillwater, Okla.

Wheeler, R. R., P. H. Weswig, W. F. Brannon, F. E. Hubbert and W. A. Sawyer. 1957. The carotene and vitamin A content of plasma and liver of range Hereford cows and their calves in the Northern Great Basin. J. Animal Sci. 16:525.

Whitehair, C. K., D. R. Peterson, W. J. Van Arsdell and O. O. Thomas. 1952. A liver biopsy technique for cattle. J. Amer. Vet. Med. Assn. 121:285.

Wise, G. H., M. J. Caldwell, D. B. Parrish, F. W. Atkeson and J. S. Hughes. 1948. Relation of typical postnatal changes in the diet of the dairy calf to the concentration of cartenoids and vitamin A in the blood serum. J. Animal Sci. 7:70.

Worker, N. A. 1956. The effect of the thyroid on the conversion of intravenously administered aqueous dispersion of carotene to vitamin A in the rat. J. Nutr. 60:447.

Worker, N. A. 1956. The effect of complete hepatectomy on the utilization by rats and rabbits of intravenously administered aqueous dispersions of carotene. Brit. J. Nutr. 10:169.

APPENDIX

TABLE I

Plasma Carotene and Vitamin A Content of the Blood of Cows During Gestation and Lactation in Experiment I (mcg/100 ml)

Cow No.	6 mo. Prepartum		Parturition		Lactation 1 mo.		Lactation 2 mo.		Lactation 3 mo.	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
					Lot I					
1	136.8	38.4	33.6	8.25	125.4	6.85	122.7	6.51	129.9	12.68
2	114.0	31.5	26.7	6.13	117.0	12.85	135.7	22.39	179.2	20.64
7	162.6	37.9	26.1	18.44	147.6	18.52	204.6	15.02	169.5	20.60
22	86.1	36.3	32.4	14.57	146.1	17.03	137.10	15.41	158.4	19.03
34	60.0	34.7	16.5	4.30	135.7	7.32	122.6	19.33	332.6	30.86
14	86.1	28.9	39.6	10.34	100.2	17.32				
24	121.8	33.6	32.0	6.81	112.8	11.03				
					Lot II					
3	96.3	36.3	22.8	9.90	371.4	18.86	309.9	19.84	316.8	18.94
4	129.6	31.0	31.2	9.32	169.5	8.05	233.0	23.88	220.3	28.50
6	123.0	41.7	33.6	8.25	273.6	18.43	286.2	28.86	299.7	18.69
17	117.3	31.0	37.2	7.07	225.6	13.92	279.0	25.96	273.7	26.86
26	117.3	34.0	25.5	8.17	213.2	7.28	185.8	17.58	244.3	32.52
31	93.0	32.6	24.9	12.68	225.6	19.86	244.2	18.31	248.1	13.79
38	119.4	31.5	22.2	5.92	284.1	21.80	185.8	20.82		
					Lot III					
12	97.5	37.9	49.5	16.02	275.7	22.77	452.7	26.99	491.4	23.12
15	121.8	36.3	31.2	9.38	322.5	24.86	351.3	23.37	299.7	21.49
28	119.4	30.0	22.2	5.45	309.8	17.07	298.9	19.84	298.9	47.59
30	67.5	27.4	25.5	4.30	298.8	22.64	311.8	23.75	359.8	25.28
35	99.9	39.5	24.3	5.36	176.1	25.20	216.7	28.13	195.9	31.54
40	112.5	35.2	38.4	7.02	316.8	17.24	345.0	18.01	273.7	15.71
45	99.0	37.9	23.4	2.04	309.8	16.52	354.5	27.93	129.9	22.56

TABLE II

Plasma Carotene and Vitamin A Content of the Blood of Calves at Parturition and During Lactation (mcg/100 ml)

Calf No.	Parturition		Lactation					
			1 mo.		2 mo.		3 mo.	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
				Lot I				
1	12.0	9.45	15.3	5.36	26.7	2.34	17.6	2.81
2	13.2	7.32	18.6	1.36	13.0	3.06	28.9	4.09
7	00.0	3.99	21.0	9.37	36.0	6.13	34.8	8.17
22	0.00	1.77	21.0	12.81	31.2	5.91	66.3	11.92
34	7.5	.08	21.1	4.51	13.1	5.45	19.9	.34
14	17.7	2.38	9.9	7.02	died			
24	13.2	1.66	14.4	.17	died			
				Lot II				
3	0.00	5.31	30.3	7.92	23.4	5.83	50.1	4.43
4	14.4	8.30	18.6	2.77	13.1	4.94	.6	6.59
6	16.5	4.77	26.7	4.26	27.9	4.17	15.3	4.81
17	16.5	1.49	13.2	4.94	31.3	7.83	34.9	10.13
26	14.4	4.90	22.1	2.60	.2	3.41	46.7	16.52
31	00.0	1.77	26.7	4.26	55.2	10.56	61.2	11.24
38	9.9	13.41	18.6	4.64	10.9	4.59	died	
				Lot III				
12	00.0	7.13	31.2	9.32	35.7	11.07	56.4	22.26
15	12.0	4.98	33.6	12.18	30.0	7.45	34.8	1.91
30	5.4	1.62	21.0	1.70	21.0	6.42	45.5	11.03
35	6.6	10.13	14.4	.17	16.5	6.22	17.6	5.66
40	7.5	1.49	31.2	17.88	23.4	7.79	22.1	.72
45	7.5	1.49	22.1	1.66	25.5	8.17	22.1	8.34
28	calf died a few hours after birth							

TABLE III

Carotene and Vitamin A Concentration of the Livers of Cows and Their Calves in Experiment I (mcg/gm dry matter)

Cow No.	Cows						Calves	
	6 mo. Prepartum		Parturition		3 mo. Postpartum		3 mo. of age	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
				Lot I				
1	17.66	311.11	6.29	36.90	8.28	13.20	1.04	2.71
2	12.52	284.82	1.16	11.55	7.91	12.36	1.32	1.82
7	40.08	570.34	9.31	37.38	16.22	43.43	1.57	1.33
22	13.73	262.92	5.97	41.02	9.05	23.01	1.25	2.68
34	10.64	128.34	3.40	8.70	8.07	10.37	2.27	4.38
14	10.89	209.62	5.25	6.13				
24	12.45	225.21	6.31	9.63	8.52	11.06		
				Lot II				
3	12.00	333.35	4.16	17.33	12.92	27.87	1.47	3.30
4	15.35	308.55	3.60	6.43	9.91	15.62	2.05	.86
6	14.62	313.87	7.99	38.09	9.49	27.90	1.96	4.81
17	20.69	270.72	4.66	24.30	16.24	50.92	1.65	5.06
26	16.62	324.00	8.11	29.93	11.06	31.20	3.18	4.24
31	13.12	208.26	5.02	41.14	14.65	35.24	3.25	3.68
38	13.90	144.27	5.95	15.85				
				Lot III				
12	16.68	181.59	8.43	28.75	28.76	39.41	1.65	4.75
15	16.48	157.70	3.77	25.25	5.36	12.38	2.98	2.67
28	19.17	255.12	5.25	40.99	25.26	58.26		
30	15.81	236.26	3.33	7.37	14.36	48.47	.45	4.20
35	9.48	182.86	3.33	2.93	7.67	20.13	3.09	7.45
40	12.75	246.68	4.39	29.05	13.00	39.47	1.85	3.01
45	19.05	327.43	4.57	17.46	16.02	28.83	3.00	9.12
Av	15.63	225.94	4.72	21.69	15.78	35.28	2.17	5.20

TABLE IV

Body Weight of Cows During Gestation and Lactation and Their Calves During Lactation (lbs)

Cow No.	5 mo. Prepartum	Parturition	Lactation 1 mo.	Lactation 2 mo.	Lactation 3 mo.	Birth Wt.	1 mo.	2 mo.	3 mo.
	Cows					Calves			
				Lot I					
1	685	605	590	630	640	57	90	130	155
2	695	665	675	690	720	62	92	130	165
7	785	705	755	795	775	60	105	155	180
14	700	710	720			56	80	died	
22	725	640	675	720	725	63	105	155	180
24	715	645	750			55	65	died	
34	670	695	740	770	810	55	80	90	150
				Lot II					
3	775	755	760	800	810	58	105	145	165
4	725	720	700	715	790	50	70	85	100
6	770	710	720	750	750	60	95	145	155
17	700	670	700	695	760	61	80	100	175
26	715	705	710	730	800	65	80	90	120
31	845	825	835	855	860	61	110	150	190
38	765	780	770	815		44	75	80	died
				Lot III					
12	730	675	710	740	725	58	90	145	165
15	740	685	700	750	775	63	90	150	165
28	730	690	715	740	790				
30	725	725	765	760	830	55	85	105	140
35	695	670	670	715	770	59	70	90	115
40	745	710	650	720	740	65	85	120	160
45	715	705	730	720	795	50	80	95	145

TABLE V

Mean Results with Fattening Steer Calves fed Varying Levels of Dehydrated Alfalfa and Alfalfa Hay
(10 steers per lot, 166 days on feed)

Lot Number and Supplement	1 C.S. Meal	2 3/4 C.S. Meal 1/4 Dehy. Alf.	3 3/4 C.S. Meal 1/4 Alf. Hay	4 1/2 C.S. Meal 1/2 Dehy. Alf.	5 1/2 C.S. Meal 1/2 Alf. Hay	6 Dehydrated Alfalfa
Ave. weights (lbs)						
Initial 10/26/55	508	518	521	525	519	524
Final 4/10/56	856	880	862	888	877	865
Total gain	348	362	341	363	358	341
Ave. daily gain	2.10	2.18	2.05	2.18	2.16	2.05
Ave. daily ration (lbs)						
Rolled milo	12.2	12.5	12.3	12.3	12.6	12.2
Cottonseed meal	1.6	1.2	1.2	.8	.8	----
Dehydrated alfalfa meal pellets		.9		1.8		3.5
Alfalfa hay			1.0		1.9	
Sorghum silage	11.9	11.6	11.5	11.5	11.3	10.7
2-1 Mineral Mix	.06	.07	.07	.07	.07	.06
Feed per cwt. gain (lbs)						
Milo	575	575	600	563	583	595
Cottonseed meal	76	55	58	36	37	
Dehydrated alfalfa		41		82		169
Alfalfa hay			46		87	
Sorghum silage	568	533	558	527	525	520

TABLE VI

Chemical Composition of Feeds Used in Fattening Tests with Steer Calves (percent as fed)

Feed	Moisture	Ash	Crude Protein	Fat	Crude Fiber	N.F.E.	Carotene mg/lb
Milo	11.33	1.67	11.56	2.91	1.95	70.58	
Cottonseed meal	7.53	7.57	38.01	5.98	14.25	26.66	
Dehydrated alfalfa meal pellets	7.35	9.85	17.90	2.97	20.58	41.35	33.2*
Alfalfa hay	5.71	10.20	15.31	2.22	28.66	37.90	22.7*
Sorghum silage	71.75	1.83	1.98	.93	6.18	17.33	1.7*

*Average of three analyses of samples taken during the trial.

TABLE VII

Plasma and Liver Carotene and Vitamin A and Average Daily Gain of Fattening Steer Calves

Steer No.	Plasma (mcg %) Nov. Car.	Nov. Vit. A	Jan. Car.	Jan. Vit. A	Apr. Car.	Apr. Vit. A	Liver (mcg/gm D.M.) Car.	Liver (mcg/gm D.M.) Vit. A	Average Daily Gain (lb)
					Lot I				
4	219.6	34.7	107.1	33.1	56.7	19.4	3.54	1.72	2.11
83			82.2	39.0	40.5	11.8	6.78	2.95	2.14
76	125.4	31.0	56.7	28.4	26.1	7.1	2.40	2.16	2.05
69	67.5	34.1	67.5	27.4	40.5	14.1	4.23	1.33	2.23
602			49.5	26.9	48.9	17.0	7.20	6.89	2.23
39			69.9	30.0	27.9	10.3	3.59	1.67	2.20
32	144.0	22.3	109.5	28.4	61.8	15.1	8.53	3.03	1.87
34	82.2	31.5	84.9	24.8	55.5	18.4	5.35	1.38	1.87
42	50.4	17.0	81.0	26.9	56.7	22.3	4.07	2.96	2.17
72	86.1	30.5	100.2	33.1	60.9	14.6	7.62	3.47	2.14
Av.	110.7	28.7	80.9	29.8	47.6	15.0	5.33	2.76	2.10
					Lot II				
112	134.1	34.7	107.1	31.5	80.1	19.9	6.65	3.32	1.96
106	139.0	35.2	83.4	28.4	78.3	21.4	9.36	4.33	2.28
16	178.5	29.4	106.2	33.1	61.8	22.9	5.76	9.17	1.96
51	183.0	27.9	95.1	32.6	90.0	26.9	2.52	4.58	2.14
89	343.5	53.2	69.0	44.6	51.0	22.3	5.46	1.47	2.53
55	330.0	35.7	106.2	40.7	95.1	34.7	5.84	21.78	2.32
37	193.5	37.4	124.2	42.9	73.5	20.3	4.10	3.95	1.99
17	39.0	16.0	96.3	26.4	108.3	24.4	8.20	3.03	2.41
28	81.0	27.4	150.0	32.6	90.0	24.4	8.38	9.28	1.93
78	69.0	30.0	86.1	32.0	100.2	24.8	7.28	10.06	2.26
Av.	169.1	32.7	102.4	34.4	82.8	24.2	6.36	7.10	2.18

TABLE VII (continued)

Steer No.	Plasma (mcg %) Nov. Car.	Nov. Vit. A	Jan. Car.	Jan. Vit. A	Apr. Car.	Apr. Vit. A	Liver (mcg/gm D.M.) Car.	Liver (mcg/gm D.M.) Vit. A	Average Daily Gain (lb)
					Lot III				
80	207.0	48.5	94.2	15.5	75.9	21.4	6.83	0.00	2.17
92	174.0	31.0	73.5	19.4	51.0	19.9	4.76	1.05	2.08
87	175.5	27.9	67.5	28.4	45.6	18.9	5.75	8.93	1.45
410	405.0	52.1	62.4	27.9	69.0	23.9	7.29	8.06	1.87
332	284.1	41.2	63.0	32.6	67.5	28.4	4.03	5.88	2.05
212	174.0	23.3	57.6	31.0	51.0	17.5	5.59	2.36	2.35
61	186.9	40.7	91.5	32.0	62.4	20.9	5.68	4.65	1.81
54	52.5	18.0	94.2	34.1	77.1	23.4	8.59	7.80	2.47
65	86.1	32.6	165.0	41.2	101.4	27.9	6.65	7.30	2.44
99	124.2	35.7	118.5	34.1	109.5	25.8	10.65	11.86	1.87
Av.	186.9	35.1	88.8	29.6	71.0	22.8	6.58	5.78	2.06
					Lot IV				
446	163.8	27.4	73.5	40.7	78.3	28.4	6.83	13.63	2.28
84	116.1	34.7	75.9	33.6	58.8	20.3	7.47	13.42	1.84
15			105.0	32.0	63.0	21.4	4.65	5.34	2.29
26	255.0	35.2	81.0	26.9	77.1	25.4	5.33	13.05	2.11
334	683.7	64.9	83.4	29.4	106.2	34.1	8.69	22.08	2.53
210	238.5	39.6	80.1	29.4	64.5	23.9	6.52	8.90	2.20
77	50.4	17.0	33.0	20.3	22.8	7.1	2.40	1.80	1.57
91	90.0	30.5	129.6	35.2	121.8	23.9	9.50	21.76	2.35
74	118.5	39.0	181.5	41.7	132.9	28.4	7.57	29.18	2.50
7	54.9	28.9	142.5	41.2	100.2	33.1	7.30	13.09	2.17
Av.	196.8	35.2	98.55	33.04	82.5	24.6	6.36	14.23	2.18

TABLE VII (continued)

Steer No.	Plasma (mcg %) Nov. Car.	Nov. Vit. A	Jan. Car.	Jan. Vit. A	Apr. Car.	Apr. Vit. A	Liver (mcg/gm D.M.) Car.	Liver (mcg/gm D.M.) Vit. A	Average Daily Gain (lb)
					Lot V				
25	138.0	24.8	67.5	25.4	42.9	18.0	5.74	4.57	1.96
2	165.5	34.7	132.9	45.7	106.2	32.6	5.24	1.98	2.40
461	274.5	44.5	117.3	33.6	87.9	28.4	5.33	7.28	2.02
79	141.0	35.2	90.0	27.4	64.5	14.6	5.87	4.65	1.81
338	229.5	29.9	39.0	28.9	54.9	24.8	5.19	4.93	2.38
208	274.5	37.9	71.4	30.0	51.0	19.9	4.28	7.56	1.75
102	93.0	40.1	184.8	52.1	136.8	34.7	11.07	5.78	2.26
20	114.9	36.8	150.0	34.1	112.5	28.4	6.50	4.19	2.29
3	54.9	31.5	107.1	36.3	75.9	27.9	9.59	16.80	2.35
52	43.5	20.3	87.0	35.8	40.5	18.4	3.49	3.87	2.35
Av.	152.9	33.6	103.7	34.9	77.3	24.8	6.27	6.16	2.16
					Lot VI				
86	187.8	43.4	95.1	34.7	81.0	26.4	6.45	10.01	2.02
23	48.9	16.0	154.5	38.4	142.5	32.0	6.67	1.60	2.26
75	128.4	33.1	55.5	22.3	60.9	19.9	4.72	11.15	2.11
14	128.4	32.6	110.4	30.5	147.9	31.0	11.80	18.83	1.99
50	231.6	34.1	105.0	30.5	83.4	28.4	7.58	32.46	1.84
113			52.5	21.9	33.6	12.7	4.56	2.79	1.87
101	91.5	30.0	201.0	41.2	99.0	34.7	12.71	4.52	1.66
46	112.5	23.9	171.0	34.1	126.0	31.0	9.30	14.99	1.96
97	62.4	26.8	99.0	30.5	81.0	24.4	13.00	11.95	2.38
Av.	123.9	30.0	116.0	31.6	95.0	26.7	8.53	12.03	2.05

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