STUDIES OF THE VITAMIN A AND CAROTENE NUTRITION OF BEEF CATTLE

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NUTRITION OF BEEF CATTLE

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INTRODUCTION

Vitamin A is distinctive in that it is formed nowhere in nature except as a product of animal metabolism, but is synthesized from carotenoids which are formed only by plants. Although many of the carotenoids possess vitamin A activity, beta carotene is the most active isomer and is the most important in the nutrition of farm animals. Jones and associates (1926) demonstrated the essentiality of vitamin A to the normal growth of calves. The importance of green feed as a source of dietary carotene in normal reproduction and lactation of beef cattle was described by Guilbert and Hart (1934).

Farmers and ranchers of Texas and Oklahoma have frequently reported the loss of cattle from symptoms similar to those of a vitamin A deficiency as described by Guilbert and Hart (1934) during a severe drouth in California. Such losses occur during the winter feeding period in herds maintained on a low quality roughage. The condition is usually most severe following a dry summer and fall when growth of forage is reduced during the latter part of the grazing season. Reports from field cases indicate that losses can be reduced by feeding limited amounts of good quality alfalfa hay.

The economic importance of this problem is self-evident, and studies of a long-time nature on the importance of vitamin A in beef cattle nutrition, particularly for successful reproduction and lactation, have been underway at this station since 1946. As a part of this program, experiments have been directed toward the rate of depletion of body stores of carotene and vitamin A of beef cows, as affected by reproduction

and lactation. Also, the relative importance of dietary intake and liver stores of carotene and vitamin A during reproduction and lactation have been investigated.

While considerable research has been done on the carotene and vitamin A nutrition of beef cattle, little is known of the efficiency with which mature ruminants utilize the carotene present in their rations. Since the carotene intake may vary from negligible amounts during the winter period, to more than 200 times the minimum requirement during the summer grazing season, it seemed desirable to study this problem with mature cattle. Preliminary studies on the digestion of carotene by steers have been reported by Van Arsdell (1951). Certain of these studies have been repeated and expanded and the results are reported herein. They involve a series of trials on the absorption of beta carotene by steers from a crude concentrate prepared from alfalfa.

REVIEW OF LITERATURE

Vitamin A is essential to the maintenance of health, vigor and reproductive capacity in all animals, according to Maynard (1951). The experimental work concerning the metabolism of carotene and vitamin A by beef cattle has been extensively reviewed by Van Arsdell (1951). Only those references pertinent to the study reported herein have been cited.

The Depletion of the Body Stores of Carotene and Vitamin A of Cattle

Hart and Guilbert (1933) reported the occurrence of avitaminosis A in beef cattle in drouth stricken areas of California where affected cattle had been maintained on rations devoid of green feed for nine months. Young cattle developed deficiency symptoms earlier than mature cows. Calves nursing cows grew slowly and exhibited clinical symptoms at 10 to 12 weeks of age. Later in the drouth period cows gave birth to weak calves which developed diarrhea and died from one to five days 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.

Guilbert and Hart (1934) conducted a series of experiments on the depletion of the carotene and vitamin A reserves of cattle. Two yearling steers removed from green pastures and placed on rations devoid of carotene developed vitamin A deficiency symptoms in 225 to 240 days.

One pregnant heifer became night blind after 195 days on a low carotene ration. Another cow fed a ration deficient in phosphorous, protein and carotene for 14 months exhibited no symptoms of a vitamin A deficiency; however, a normal calf dropped by this cow and nursing her during the period, died of malnutrition and avitaminosis A at 5 months of age. Four heifers which were fed one pound of alfalfa hay daily in addition to the low-carotene ration produced normal calves which developed vitamin A deficiency symptoms at 3 to 5 days of age. These workers analyzed the livers of numerous animals for carotene and vitamin A. They found that the liver stores of vitamin A in beef cows may vary as much as 10-fold depending on the carotene intake of the cow during the last few months before slaughter. Newborn calves were found to have very low stores of vitamin A and carotene regardless of the type of ration their dam had received during gestation.

In further studies of the carotene and vitamin A nutrition of beef cattle Guilbert and Hart (1935) found that 67 to 93 percent of the body stores of carotene and vitamin A are found in the liver. The body stores appear to increase as the animal grows older as is evidenced by the fact that aged cows had six times greater total liver stores than younger animals under comparable conditions. The minimum daily carotene requirement of cattle based on the prevention of night blindness was found to be between 26 and 33 micrograms per kilogram of body weight. The need for larger amounts of carotene during late gestation and lactation was recognized.

Jones et al. (1938) reported studies of the time required to produce night blindness in steer calves and yearlings raised on Texas ranges. The steers were fed 2.5 pounds of cottonseed meal and 2.2 pounds of

ground white kafir daily with cottonseed hulls ad libitum. In the winter of 1934-35, ten steer calves became night blind in 139 days. In 1935-36, the average depletion time for 48 yearling steers was 142 days as compared to 136 days for a group of 40 steer calves. The range of depletion time required by each animal varied from 91 to 231 days for the yearlings and 101 to 206 days for the steer calves. The following year 50 steer calves were depleted in an average of 138 days (range of 96 to 194 days) on the carotene deficient ration. No symptoms of avitaminosis A other than night blindness were observed in these studies. Five night blind steers were fed a fattening ration which supplied 450 micrograms of carotene per hundred pounds of body weight for an extended period of time. Four of the steers had died due to severe vitamin A deficiency at the time the report was written. The one steer which remained alive had been on the ration for 607 days beyond the night blind state while death occurred in the other four steers at 485, 145, 472 and 154 days after night blindness was observed. All five of the steers had required more than 100 days of depletion before becoming night blind. From the results of an extensive series of fattening trials using night blind steers, these workers recommended 1600 micrograms of carotene per hundred pounds of body weight for optimum feedlot performance.

In later reports, Riggs (1940) and Jones et al. (1943) summarized the vitamin A depletion studies conducted over a seven-year period and involving more than 300 steers and heifers. They observed that the depletion time of the cattle varied with age and from year to year. Since it has been previously reported that body stores of carotene and vitamin A increase as the cattle grow older, these findings confirm the work of Guilbert and Hart (1935). In an explanation of the variation of depletion

time from year to year in animals of comparable age and size, these workers presented data showing that the shortest depletion periods occurred following seasons in which rainfall and forage growth was below normal. The average time required to deplete 450 pound steer calves when the rainfall from July to October was 12 to 15 inches was 137 days as compared to 107 days when the July-October rainfall was only 5 inches. In another study, steer calves taken from summer range were depleted in 98 days while similar calves placed on depletion from winter range became night blind in 46 days.

The rate of depletion of hepatic stores of vitamin A and carotene by beef steers decreases as the liver reserves are reduced according to the reports of Frey and Jensen (1946), (1947). From a group of 140 yearling Hereford steers, 22 representative animals were slaughtered to estimate the initial liver stores of carotene and vitamin A. The remaining 118 steers were divided into two dietary groups. Ninety-eight of the steers were fed a high carotene maintenance ration. The steers fed the fattening ration were subdivided into 4 groups and slaughtered after 41, 76, 119, and 166 days in the feed-lot. The steers receiving the high carotene maintenance ration were subdivided into 2 groups and slaughtered after 119 and 166 days of feeding. Although the steers fed the maintenance ration received an average of 963 milligrams of carotene per head daily, their liver stores of carotene decreased 29 percent and their liver reserves of vitamin A dropped 82 percent during the 166-day feeding period. The steers fed the fattening ration received an average of 309 milligrams of carotene daily; their hepatic reserves of carotene and vitamin A decreased 76 and 97 percent respectively during the experiment. No symptoms indicative of avitaminosis A were observed during the

study. The gains of the animals were satisfactory for the type of rations fed. When the hepatic stores of vitamin A of the steers fed the low carotene fattening ration 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 proportionate to the total liver reserves.

Frey et al. (1947) studied the effect of vitamin A supplementation of a carotene-deficient fattening ration on the feed-lot performance of Hereford steer calves. One hundred and fourteen steers were divided into six lots of nineteen animals each. The steers of lot I were slaughtered at the beginning of the experiment to establish the 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 pound of body weight; lot IV, 100 I. U.; lot V, 200 I. U.; 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 experiment symptoms of vitamin A deficiency appeared in the steers of lot II. After 277 days in the feed lot, 8 of the 10 steers remaining in lot II exhibited symptoms of avitaminosis A. Hepatic stores of carotene and vitamin A 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 micrograms per 100 milliliters to 13.7 and 5.2 at 166 and 277 days respectively. Although serum vitamin A levels of the steers of lot III remained near the initial value, the liver reserves dropped from 47.1 to 1.4 micrograms per gram of liver. The liver vitamin A content of steers in lot III dropped from 47.1 to 17.4 micrograms per gram while

the plasma vitamin A increased 39 to 48.9 micrograms per 100 milliliters. Both the serum and hepatic levels of vitamin A increased for the steers of lots V and VI during the experiment. The steers of lot II gained slower and produced carcasses inferior to those of the other 4 lots. There was no difference in average daily gain or average carcass grade between the 4 lots of steers receiving the vitamin A supplements.

The effect vitamin A and carotene intake during the first 90 days of life of dairy calves on the vitamin A depletion time thereafter was studied by Jacobson et al. (1949). Calves permitted to nurse their dams on pasture for 90 days could be depleted in 113 to 120 days. In order to build up similar vitamin A stores in calves fed a limited whole milk ration, it was necessary to supplement them with 50,000 I. U. of vitamin A daily for 50 days or more. The depletion time was reduced by 50 percent when lower levels of supplementation were used. Calves on the limited whole milk ration without vitamin A supplementation could be depleted in 2 to 4 weeks.

From the research conducted to date, it appears that the rate at which the body reserves of carotene and vitamin A are depleted is directly related to the total initial stores. However, most of the experimental work on the depletion of liver stores has been conducted with steers and young heifers. Application of these results to the range cow herd is somewhat questionable since the hormonal mechanisms and body processes of the mature beef cow during reproduction and lactation differ greatly from those of young heifers and steers. The need for additional study of this problem is quite evident.

The Importance of Vitamin A in Reproduction and Lactation

The work of Guilbert and Hart (1935) indicates that the carotene requirement of beef cattle during late gestation and early lactation may be as much as 5 times the maintenance requirement of 26 to 33 micrograms per kilogram of body weight. Satisfactory reproduction performances were obtained from beef cows which had received a maintenance allowance of carotene during the first two-thirds of gestation and 5 times this amount during the last 90 days before calving. Calves nursing cows fed carotene-deficient rations developed symptoms typical of a vitamin A deficiency.

Davis and Madsen (1941) suggested that the carotene requirement of beef cattle for reproduction was between 45 and 60 micrograms per kilogram of body weight. This recommendation was based on the satisfactory reproductive performance of 2 heifers which had been depleted to a night blind state and then given a daily allowance of 60 micrograms of carotene per kilogram of body weight. Three similar heifers which received 30 to 45 micrograms of carotene produced calves afflicted with avitaminosis A.

Dairy cows of the Jersey breed reproduced normally when maintained for long periods of time on a carotene intake of 45 micrograms per pound of body weight in the experiments conducted by Kuhlman and Gallup (1940). Cows fed rations providing a lower intake of carotene produced a much lower percentage of normal calves, and had greater difficulty with retained placentas after calving. This report included 31 gestation periods recorded from a herd of 17 Jersey cows.

Kuhlman and Gallup (1941) observed that the carotene intake of Jersey cows during lactation could be reduced below the level required for

normal reproduction without an adverse affect on the total milk yield. The results of 22 complete lactation periods from twelve cows indicated that the carotene requirement for maximum milk production was greater during the early part of lactation than it was in the latter part. Cows maintained on low carotene intakes during late gestation followed by difficult parturition did not produce a normal amount of milk.

In a later report, Kuhlman and Gallup (1942) concluded that a satisfactory conception rate can be obtained in dairy cows if the carotene intake is maintained at the same rate recommended for normal calving performance. This observation was based on 58 conceptions in 27 grade Jersey cows from 80 services. In 21 cases where cows received an average daily carotene intake of 20 to 39 micrograms per pound of body weight during the 90-day period preceding service, 1.99 services were required per conception. When the daily carotene intake was 40 to 59 micrograms, 60 to 99 micrograms, and 100 to 353 micrograms, 1.35, 1.15, and 1.23 services per conception were required respectively, in 23, 15, and 21 cases.

Ronning et al. (1953) summarized the results of an 8-year study of the carotene requirements of Guernsey cattle for reproduction. The 4 levels of carotene intake studied were: 30-59 micrograms, 60-89 micrograms, 90-119 micrograms and 120-150 micrograms per pound of body weight. The results of 72 gestations indicate that an intake of 90 micrograms of carotene per pound 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, blind calves and weak calves resulted. Since most of the abortions occurred prior to 180 days of gestation, these workers suggest that the critical period of

vitamin A nutrition of the pregnant cow may be earlier than the last 90 days of gestation. It was observed that the gestation periods of the cows receiving the lower carotene intakes were a few days shorter. There was no apparent relationship between conception and the carotene intake during the service period in this experiment.

From a series of studies with dairy cows, Meigs and Converse (1936) and Converse and Meigs (1938) reported that the carotene requirement for the latter part of the gestation period was between 80 and 120 micrograms per pound of body weight.

Braun and Carle (1943) observed that the vitamin A content of the bovine fetal liver, although low, was in direct relationship to the mother's diet. The livers from twenty fetuses aborted by cows exposed to Brucella abortus were analyzed for vitamin A content. Vitamin A storage in some of the cows was also determined from liver samples obtained by partial hepatectomy at the time of abortion. The cows studied were from the following 4 dietary groups: I, low carotene ration; II, low carotene ration plus 400,000 I. U. of vitamin A twice weekly; III, green pasture; IV, green pasture plus 400,000 I. U. of vitamin A twice weekly. The average fetal liver stores were 1.7, 14.1, 6.6, and 10.7 I. U. per gram for treatments I, II, III and IV respectively.

The liver reserves of carotene and vitamin A of the new-born dairy calf may be influenced markedly by the prepartum diet of the dam according to the report of Spielman et al. (1946a). Thirty-three cows were divided into 4 groups 60 days prepartum and fed the following rations: lot I - wheat straw and a concentrate mixture; lot II - hay, corn silage, and concentrate mixture; lot III - the same ration as II plus 1 million I. U. of carotene daily; lot IV - the same as II plus 1 million I. U.

of vitamin A daily. The plasma carotene levels of the calves were not affected by the maternal treatments, but the plasma vitamin A levels of the calves produced by the cows supplemented with carotene were twice as high as those of lots I and II. The plasma vitamin A levels of the calves produced by the vitamin A supplemented cows were 4 times as high as those of lots I and II. The liver stores of carotenoids in the newborn calves varied directly with the carotene content of maternal prepartum diet. The average total liver storage of vitamin A and carotene in the calves produced by the vitamin A supplemented cows was 97,177 I. U. Analysis of the colostrum produced by these cows demonstrated that its vitamin A and carotene content is significantly influenced by the prepartum ration of the cows, (Speilman et al. 1946b). Colostrum secreted by the cows whose rations had been supplemented with vitamin A contained 2 to 3 times as much vitamin A as that secreted by the cows on the other treatments. The carotene content of the colostrum of the carotene supplemented cows was considerably higher than that of cows of the other three lots.

Wise et al. (1946) observed that massive doses of vitamin A administered to dairy cows during late pregnancy caused an increase of liver stores and plasma levels of vitamin A in newborn calves. Although the vitamin A content of the colostrum varied widely in this study, it also was increased by prepartum vitamin A supplementation.

The vitamin A and carotene contents of the plasma of dairy cows decrease markedly at the time of parturition and beginning lactation according to the report of Sutton et al. (1945). In a study using 28 cows of the 4 major dairy breeds, they observed that the maximum decrease in plasma vitamin A occurred 3 days post partum while that of plasma carote-

was 1 week after parturition. These workers also reported that the average total output of vitamin A and carotene in the colostrum in the first three days was 48,847 and 56,524 micrograms respectively. The rations of the cows consisted of good quality alfalfa hay, corn silage, and a concentrate mixture.

The placental and mammary transfer of vitamin A by goats and swine can be significantly increased by the addition of large amounts of vitamin A to the diet of the pregnant female as was shown by Thomas et al. (1947). The average total liver stores of vitamin A and carotene in newborn kids was increased from 36 I. U. to 2792 I. U. by the daily addition of 100,000 I. U. of vitamin A to the ration of the does during the last 42 days of gestation. Supplementing the daily ration of sows for the last 32 days before farrowing with 406,000 I. U. of vitamin A resulted in average total vitamin A liver stores in their pigs of 4615 I. U. as compared to 254 I. U. for pigs produced by sows fed the same ration without the vitamin A supplement. Colostrum produced by goats on normal rations had larger concentrations of vitamin A than that of sows on normal rations. Feeding the massive doses of vitamin A during late pregnancy markedly increased the potency of the colostrum of both the does and sows.

Fountain et al. (1948) observed that the plasma vitamin A levels of newborn calves produced by cows fed on green pasture during the dry period was higher than those of calves produced by cows fed grain, hay and green pasture. Plasma vitamin A levels for calves produced by cows supplemented with large doses of vitamin A ester or alcohol during the dry period were comparable to those of the calves whose dams were fed only pasture.

Esh et al. (1948) studied the effect of massive doses of vitamin A with and without soya-phosphotides on the placental and mammary transfer of vitamin A by dairy cows. Twenty-six Jersey and Holstein cows were divided into the following 4 dietary groups during the last 30 days of gestation: I, normal herd ration consisting of silage, hay, and a concentrate mixture; II, herd ration plus 10 grams of soya-phosphotides daily; III, herd ration plus 1 million I. U. of vitamin A daily; IV, herd ration plus 10 grams of soya-phosphotides and 1 million I. U. of vitamin A daily. The vitamin A content of the colostrum and the calf livers and plasma were not affected by prepartum feeding of soya-phosphotides alone; however, supplementation of the maternal prepartum rations with vitamin A or vitamin A and soya-phosphotides increased both placental and mammary transfer of vitamin A. In all cases the highest average levels of vitamin A in the colostrum, calf livers and plasma were observed where the cows were supplemented with both soya-phosphotides and vitamin A. The feeding of soya-phosphotides or vitamin A or a combination of the two did not prevent the decrease in plasma vitamin A and carotene levels of the cows at parturition. However, the levels did not drop as low when the cows were supplemented with vitamin A with or without soya-phosphotides.

A study of the placental and mammary transfer of vitamin A by sheep and swine was conducted by Eaton et al. (1949). The supplementation of rations fed to ewes and sows during the last 30 days of gestation with vitamin A or a combination of crude soybean lecithin and vitamin A increased plasma and liver levels of vitamin A in newborn lambs and pigs. The addition of soya-lecithin to the vitamin A supplement did not materially increase the transmission of vitamin A to the newborn pigs or

lambs above that of animals receiving an equal amount of vitamin A alone. In all cases the plasma and liver levels of vitamin A of the pigs and lambs at 30 days of age were higher for the supplemented animals than for the control animals.

From an extensive series of studies with rats Henry et al. (1949) concluded that the vitamin A contents of the milk of the females and the livers of their young are influenced more by the vitamin A content of the maternal diet during lactation than by the maternal stores of vitamin A. Liver reserves of young rats increased three-fold during the nursing period when the mothers had high liver stores of vitamin A but were given no dietary vitamin A. A six-fold increase in the liver stores of the young occurred when the dams were supplied with dietary vitamin A in the absence of liver stores during the nursing period.

Van Arsdell et al. (1950) studied the effect of 3 levels of carotene intake, 38, 75, and 106 milligrams daily, on the performance of Hereford cows during the last 45 days of gestation and the first 30 days of lactation. Blood samples and milk samples were collected periodically from the cows and their calves. Although the plasma vitamin A and carotene contents of the cows dropped quite low no clinical symptoms of avitaminosis A were observed. Plasma carotene levels of the cows were closely correlated to the carotene intake. The plasma vitamin A and carotene levels of the calves at 30 days of age were directly related to the carotene intake of the cows. However, no differences in health or vigor of the calves were observed.

Thus, it has been demonstrated that placental transfer of vitamin A and carotene is relatively poor in all species, while mammary transfer during the early stages of lactation is good. Massive doses of vitamin A

during late gestation have been effective in increasing placental transfer. A large portion of the literature cited has concerned studies in which dairy cattle were the experimental subjects. However, the varied response of different dairy breeds to the same intake of carotene makes it difficult to apply the results obtained to beef cattle. Since a rather limited amount of research work has been done concerning the vitamin A nutrition of the beef cow and calf, the need for additional study is apparent.

Digestion and Utilization of Carotene

Whitnah et al. (1937) observed a relatively high excretion of carotene by dairy cows and heifers fed natural rations that supplied from 0.003 to 2.51 milligrams of carotene per kilogram of body weight daily. Six yearling heifers and seventeen lactating cows were studied in these experiments. The cows were somewhat more efficient in utilizing carotene than the heifers but in all groups studied, over 75 percent of the ingested carotene was recovered in the feces. Some of the animals were in a very pronounced negative carotene balance as was shown by the daily carotene excretion of more than 1,000 percent of the intake. Serum carotene concentrations varied with the level of intake and with individual cows. These workers also observed that carotene excretion by cows transferred from pasture to carotene deficient rations decreased 98 percent during the first week; 88 percent of the remaining fecal carotene disappeared during the second week.

Carotene retention by cattle is quite variable as shown by the experiments of Seshan and Sen (1942). Four lactating cows receiving from 6.85 to 10.35 milligrams of carotene daily were used in a carotene

balance study. All four cows were in a very pronounced negative carotene balance as is shown by the daily fecal carotene excretion varying from 17 to 24 milligrams and daily milk carotene content 2.6 to 3.0 milligrams. After the completion of this study, the carotene intake of the cows was increased to 190 milligrams per head daily and another balance study was conducted. Two of the cows remained in negative carotene balance while two were in a slightly positive balance. These workers explained the negative carotene balances on the basis of depletion of body reserves of carotene. To further study the problem, Seshan and Sen conducted a carotene balance study using four bullocks that had been fed a low carotene ration for six months. They established the daily carotene excretion of each bullock from the basal ration. The animals were then given a single feed of 500, 1000, 1500, or 2000 grams of green berseem (Egyptian clover) containing 48.78 micrograms of carotene per gram. The feces were collected and analyzed daily until the carotene excretion had returned to the previous level. The following carotene retention values were calculated from the data:

Animal No.	1	2	3	4
Carotene intake (milligrams)	24.39	38.78	73.17	97.56
Percent of carotene retained	25.5	50.2	40.2	37.6

The levels of intake were reversed and the procedure was repeated. The results of this trial were:

Animal No.	1	2	3	4
Carotene intake (milligrams)	78.48	58.86	39.24	19.62
Percent of carotene retained	40.9	35.4	49.3	34.1

It should be noted that in these trials, the percent of the carotene retained was relatively constant regardless of the level of intake.

Chanda et al. (1951) compared the apparent digestibility of carotene by cows and goats. Using dry grass as a source of carotene and the

chromium oxide-carotene ratio to measure apparent digestibility, they found that goats are more efficient than cows in the digestion of carotene. The apparent digestibility values of carotene fed to four goats at a level of 1.20 milligrams per kilogram of body weight were 67.4, 62.9, 61.8, and 58.9 percent. Six cows receiving 1.10 milligrams of carotene per kilogram of body weight gave the following apparent digestibility values for carotene; 59.3, 54.0, 54.5, 54.4, 57.1, and 55.5 percent. These workers suggest that longer digestion trials would allow more accurate measures of carotene utilization by cows and goats.

Since the goat is believed to have a more active thyroid than the cow, Chanda et al. (1951) studied the effect of thyroxine and thiouracil on the digestion of carotene by these two species. Six cows and six goats were used as experimental subjects and the general procedure was the same as described in the previous experiment by these workers. The average apparent digestibility of carotene by the two control cows was 57 percent. Administration of thyroxine to two cows increased the apparent digestibility of carotene to 71.5 percent while treatment of two other cows with thiouracil depressed the apparent digestibility of carotene to 49.5. Similar results were obtained with the goats; however, the increase due to thyroxine treatment was not so great and the decrease due to thiouracil administration was greater. These workers interpret these data to support the theories that the goat has a more active thyroid than the cow and that the thyroid hormone is involved in carotene and vitamin A metabolism.

In a study of the effect of level of carotene intake on the digestion of carotene by yearling Hereford steers Van Arsdell (1951) conducted a series of five carotene balance trials. The steers had been fed a low

carotene ration for four months before the initiation of the first balance trials. The following levels of carotene intake were studied: 120, 240, 480, 960, and 6000 micrograms of carotene per kilogram of body weight. A crude carotene concentrate derived from alfalfa was administered daily by gelatin capsule to meet the specified allowances. The four lower levels of intake were studied in the first four trials with each steer on a different level of intake in each trial. In the fifth trial all three steers were placed on the high intake, 6000 micrograms per kilogram of body weight. The percent of carotene excreted by the individual steers was relatively constant in all five trials. The average percentage excretion of carotene for all steers in all trials was 36.6. There was a trend toward a greater retention of carotene when the steers were receiving the higher intakes of carotene. Carotene and vitamin A determinations were made on liver biopsy samples and blood samples collected at the end of each trial. The carotene and vitamin A contents of the liver and plasma increased or decreased as the carotene intake was increased or decreased respectively.

Growing chicks are able to utilize carotene more efficiently than mature rats according to the results of Kemmerer and Fraps (1938). When the diet of rats contained 20 parts per million of carotene from alfalfa leaf meal, apparent digestibility values varying from 18 to 23 percent were obtained. An apparent digestibility value of carotene from the same source fed to chicks at the same level of intake was 29.1 percent. Reduction of the intake to 1.2 ppm for the rats and 1.1 ppm for the chicks caused the apparent digestibility of carotene to increase to 43 and 63.9 percent respectively. When a Wesson oil solution of carotene was incorporated into the rats' ration to provide 10.5 ppm of carotene, a 51.2

percent apparent digestibility of carotene was observed. The apparent digestibility of carotene from alfalfa leaf meal fed to rats at the same level of intake was only 22.4 percent. These workers suggest that the utilization of dietary carotene is influenced by the level of intake, the nature of the carrier and the species of animal.

The nature of carotene preparations used in carotene balance experiments was further studied by Goodwin and Gregory (1948). Oral doses of crystalline beta-carotene dissolved in arachis oil or dispersed in water was administered by stomach tube to groups of five rabbits. Nearly 100 percent of the carotene administered in the arachis oil preparation was recovered in the feces; whereas, only 13.6 percent of the carotene given in the colloidal form was accounted for in the feces. To determine if the carotene administered to the latter group had been destroyed by the digestive fluids or absorbed, the workers mixed the colloidal carotene solution with rabbit intestinal contents and incubated the mixture at 37° C. Since there was no loss of carotene during the in vitro incubation period, they concluded that carotene absorption was enhanced by dispersion of the pro-vitamin in water.

Vavich and Kemmerer (1950) studied the effect of size, rate of growth, and food consumption on the storage of vitamin A from dietary carotene. They found that smaller rats stored significantly greater amounts of vitamin A from a standard intake of carotene than did larger rats. No differences in carotene utilization could be attributed to differences in rate of growth or food consumption.

A negative carotene balance in sheep was observed by McGillivray (1951). In come cases the carotene excretion was 160 percent of the intake. In order to study the origin of the fecal pigment, the daily

carotene intake and excretion were determined on four pasture fed lambs during a period just before slaughter. Immediately after slaughter, samples of rumen and intestinal contents were collected at twenty different points along the gastro-intestinal tract. The samples were analyzed for carotene and lignin and the carotene-lignin ratios were calculated. A rather marked decrease in the carotene-lignin ratio was observed in the upper section of the small intestine while a progressive increase occurred in the ileum and cecum. McGillivray interprets these data as evidence that carotene is synthesized by the micro-organisms of the ileum and the cecum.

A limited number of experiments concerning the efficiency of carotene utilization by cattle have been conducted. From these, it may be concluded that carotene digestibility varies widely and is influenced to some degree by endocrine secretions, such as thyroxine, and by the nutritional history of the animal. Studies conducted with other species (rats, rabbits, chicks and sheep) indicate that the size and species of the animal, the nature of the carotene preparation administered, and the level of carotene intake may affect the apparent digestibility of carotene.

EXPERIMENTAL OBJECTIVES

Experiments were designed to study the following problems:

Part I The effect of level of carotene intake on the utilization of the dietary carotene by steers;

Part II The relative importance of dietary intake and liver stores of vitamin A and carotene to beef cows during reproduction and lactation;

Part III The reproduction and lactation performance of beef cows fed low-carotene rations.

PART I

THE EFFECT OF LEVEL OF CAROTENE INTAKE ON THE PERCENTAGE OF DIETARY CAROTENE EXCRETED BY STEERS

It has been demonstrated that carotene excretion by cattle is quite variable. Since the intake of beef cattle also varies widely, this experiment was conducted to study the relationship between the level of carotene intake and the percent of the ingested carotene excreted.

Experimental Procedure

Six yearling Hereford steers which had been grazing green pasture for two months were selected for the experiment on June 1, 1952. The steers were fed the following daily ration during a six-week adjustment period: cottonseed meal, 2 pounds; ground milo, 4 pounds; and wheat straw ad libitum. The steers had access at all times to salt and mineral mixture (equal parts of salt, ground limestone and bone meal). At the completion of the adjustment period ad libitum feeding of wheat straw was discontinued and each steer was given six pounds of chopped wheat straw with the same daily concentrate allowance described above. The amounts of apparent beta-carotene in the feedstuffs were: Wheat straw 0.60, ground milo 0.10, and cottonseed meal 0.17 micrograms per gram. The daily carotene intake from the ration was computed and added to that given by capsule to arrive at the total daily carotene intake of each steer.

The steers were fed in individual stalls equipped with stanchions

and were allowed the freedom of a large concrete exercise pen between feeding periods. Feces were collected by means of a harness and bag similar to the type designed by Garrigus (1939). The feces were collected once daily, weighed and representative aliquots were taken for analysis. The samples were kept in tightly sealed jars, and were refrigerated at about 4° C. The feces samples were analyzed for carotene by a method adapted from the alcoholic KOH extraction method of the A. O. A. C. (1945). Analyses were made after each three days of collection to prevent loss of carotene during storage. Three consecutive three-day collection periods preceded by a ten-day preliminary period were considered as one complete trial in this experiment. The carotene excretion from the basal ration was determined by conducting one trial with each steer without the addition of carotene to the ration. The excretions of apparent beta-carotene thus obtained were subtracted from those obtained while supplementing the steers with carotene.

A carotene concentrate, derived from alfalfa and containing six micrograms of carotene per gram, was administered by gelatin capsule daily to meet the specified allowance. Thirty micrograms of carotene per kilogram of body weight (as reported by Guilbert and Hart, 1935) was used as the minimum requirement in computing the different levels of carotene intake. The weight of the steers at the beginning of each trial was used in calculating the amount of carotene concentrate to be administered during the trial. The rate of supplementation to the various steers during the four trials was:

Trial	I	II	III	IV
Steer				
1	4 x m.r.	32 x m.r.	16 x m.r.	8 x m.r.
2	8 x m.r.	4 x m.r.	32 x m.r.	16 x m.r.
3	16 x m.r.	8 x m.r.	4 x m.r.	32 x m.r.
4	16 x m.r.	8 x m.r.	4 x m.r.	32 x m.r.
5	32 x m.r.	16 x m.r.	8 x m.r.	4 x m.r.
6	32 x m.r.	16 x m.r.	8 x m.r.	4 x m.r.

x m.r. = multiples of minimum requirement fed.

Steers 3 and 6 went off feed during trial I; consequently, a collection of feces was not made from these animals during that trial.

Results and Discussion

The data obtained on the percent of the ingested carotene excreted in the feces are presented in table 1. The relatively constant percentage excretion of carotene by steers receiving varying levels of carotene intake as was observed by Van Arsdell (1951) was confirmed in this experiment. However, the dietary carotene excreted by the steers in this study was considerably more than that observed by Van Arsdell who reported an average excretion of 38.4 percent of dietary carotene as compared to 60.6 percent obtained in this study. Since the steers used in Van Arsdell's experiment had been depleted for a longer period of time and the liver stores of carotene and vitamin A of his animals were relatively low at the beginning of the experiment, it seems possible that the utilization of dietary carotene may be related to the total body stores of the animal at a particular time. This theory is supported by the fact that as the experiment progressed there was in increased percent of carotene excreted by all steers. The average carotene excretion by all steers in each trial was 51.1, 61.9, 64.8 and 61.1 percent for trials I, II, III and IV, respectively. Any further attempt to compare the

TABLE I

Carotene Balance Data Obtained in the Study of the Effect of Level of Carotene Intake on Carotene Utilization by Steers

Carotene Allowance	Trial No.	Steer No.	Average Daily Carotene Intake Mg.	Average Daily Carotene Excretion Mg.	Percent Carotene Excretion
	I	1	35.7	15.8	44.3
	II	2	39.0	23.3	59.7
	III	3	38.7	26.0	67.2
4 x m.r	III	4	30.5	19.7	64.6
	IV	5	34.4	22.0	62.1
	IV	6	37.6	22.2	59.0
	Average				59.5
	I	2	75.8	42.1	55.5
	II	3	76.9	48.9	63.6
	II	4	60.0	38.9	64.8
	III	5	65.4	41.7	63.8
8 x m.r.	III	6	72.5	44.0	60.7
	IV	1	73.6	46.4	63.0
	Average				61.9
	I	4	113.5	58.1	51.2
	II	5	128.7	83.1	64.6
16 x m.r.	II	6	146.2	85.4	58.4
	III	1	144.0	92.9	64.5
	IV	2	153.8	99.2	64.5
	Average				60.5
	I	5	248.7	135.9	54.6
	II	1	281.4	169.7	60.3
	III	2	316.3	214.8	67.9
32 x m.r.	IV	3	322.8	193.0	59.8
	IV	4	244.3	142.7	58.4
	Average				60.2

results obtained by Van Arsdell with those obtained in the experiments reported herein would be hampered by differences in environmental conditions, carotene concentrate administered, methods of feeding and methods of collection.

The constant percentage excretion of ingested carotene by cattle suggests that the disappearance of carotene from the intestinal contents is related to the concentration of carotene in the medium. It is apparent that considerably more carotene disappeared from the gastro-intestinal tract when the higher levels of carotene were administered to the steers. Goodwin and Gregory (1948) demonstrated that carotene is relatively stable in the intestinal contents of rabbits. If carotene is equally resistant to destruction in the gastro-intestinal tract of cattle, it seems logical to conclude that carotene absorption by cattle is regulated by the concentration of carotene in the intestinal contents at the site of absorption. However, if destructive forces which attack carotene are present in the intestinal contents of cattle, larger amounts of carotene would be destroyed as the concentration of carotene in the intestinal medium increased. Thus, it appears possible that the percentage of ingested carotene recovered in the feces of cattle may be determined by the combined effects of carotene absorption and destruction.

PART II

THE RELATIVE IMPORTANCE OF DIETARY CAROTENE AND LIVER STORES OF CAROTENE AND VITAMIN A TO BEEF COWS DURING REPRODUCTION AND LACTATION

The carotene and vitamin A nutrition of cattle is greatly influenced by their ability to store large quantities of this vitamin while grazing green pastures. Questions have been raised as to whether the body stores of the cow can be mobilized to an extent sufficient to meet the needs of pregnancy and lactation during periods of low carotene intake. These experiments were designed to study the utilization of dietary carotene and the liver stores of carotene and vitamin A by beef cows during reproduction and lactation.

EXPERIMENT I

Experimental Procedure

Ten 2-year-old Hereford cows in the second and third month of pregnancy were selected in March, 1952, for this experiment. During gestation, they were fed the following low-carotene ration per head daily: cottonseed meal, 2½ pounds; ground milo, 1 pound; dried beet pulp, 2 pounds; cottonseed hulls, 2 pounds; and wheat straw or dry, weathered, range grass, ad libitum. During lactation, the low-carotene ration for each cow was composed of cottonseed meal, 3 pounds; ground milo, 4 pounds; and wheat straw, ad libitum. The cattle had access at all times to salt and a mineral mixture composed of equal parts of ground limestone,

steamed bone meal and salt. The basal ration was calculated to meet the recommended allowances of the National Research Council for all essential nutrients for pregnant and lactating cows, with the exception of carotene. During the experiment, the cows were maintained on concrete floors and had no access to green feeds.

At the beginning of the experiment, blood samples and liver biopsy samples were collected using the technique of Whitehair and associates (1952). Assignment of the cows to the various treatments was based on liver stores of carotene and vitamin A. To study the ability of cows to mobilize liver stores during lactation, high liver levels were desirable; consequently, those animals with the highest liver stores were assigned to Lots III and IV. The treatments and number of cows in each were were: Lot I, no supplemental carotene, 2 cows; Lot II, supplemental carotene during lactation, 3 cows; Lot III, supplemental carotene during gestation, 3 cows; Lot IV, supplemental carotene during gestation and lactation, 2 cows. The levels of carotene administered were in accordance with the National Research Council's recommended daily allowances for beef cows of 55 milligrams of carotene per day during gestation and 300 milligrams during lactation. A crude carotene concentrate* derived from alfalfa and containing 6 milligrams of carotene per gram was administered in gelatin capsules to meet the specified allowances. The capsules were administered twice weekly during gestation and three times weekly during lactation.

In addition to the liver and blood samples collected at the beginning

*The carotene concentrate was supplied by the Chlorophyll Chemical Corp., McAllen, Texas.

of the experiment, liver samples were taken from the cows and their calves immediately after parturition and at the end of three months of lactation. Blood samples were collected from the cows at monthly intervals before parturition. Additional blood samples were taken from the cows and their calves immediately after parturition and at two weeks, one month, two months and three months post partum. Colostrum samples were collected after parturition and milk samples were obtained at 2, 4, 7, 14 and 21 days, and at the end of 1, 2, and 3 months of lactation. The calves were separated from the cows four hours before milk samples were collected. One quarter of each cow's udder was milked completely to obtain a representative milk sample. The blood, milk and liver samples were analyzed for carotene and vitamin A. Liver samples were analyzed according to the method of Gallup and Hoefer (1946), plasma by the method of Kimble (1939), and milk by the method of Lesher et al. (1945).

Results and Discussion

The average liver levels of vitamin A and carotene for the four lots of cows and calves are presented in Table 2. Plasma and milk levels of vitamin A and carotene for the cows and calves are shown in Table 3. Similar data for the individual animals are presented in Tables 8, 9, 10, 11, 12, and 13, appendix.

Examination of the liver composition of the cows at the beginning of the experimental period and at parturition shows that the amount of carotene administered to the cows of Lots III and IV was insufficient to maintain liver stores of vitamin A at their initial level. Cows receiving carotene supplementation during gestation had about twice as much vitamin A in their livers at parturition as those maintained on

TABLE 2

Average Vit. A and Carotene Content of Livers of Beef Cows, and Vit. A Content of Livers of Their Calves in Experiment I (Mcg/gm dry matter)

	Lot No.	6 mo. Prepartum	At Parturition	3 mo. Post Partum
			Cows	
Liver Vit. A				
	I	68.9	5.7	1.7
	II	70.6	9.4	18.9
	III	122.6	20.6	7.4
	IV	92.2	14.3	23.4
Liver Carotene				
	I	4.0	2.3	1.1
	II	4.7	2.7	3.7
	III	5.9	2.6	2.4
	IV	3.9	3.5	5.2
			Calves	
Liver Vit. A				
	I		4.2	1.9
	II		3.4	14.2
	III		2.6	5.1
	IV		3.0	22.3

the depletion ration. The amount of carotene provided the cows of Lots II and IV during lactation resulted in an increase in liver stores of vitamin A despite milk production. It is recognized that the stores of vitamin A at the beginning of the experimental period were high, reflecting a high intake of carotene during the previous summer, and that failure to maintain them is not necessarily indicative of an inadequate carotene intake.

Liver stores of vitamin A in the newborn calf was not related to the carotene intake of the dam during gestation, or her liver stores at

TABLE 3

Average Vit. A and Carotene Content of Plasma and Milk of Beef Cows and Vit. A Content of Plasma of Their Calves in Experiment I
(Mcg/100 ml)

	Lot No.	6 mo Prepartum	3 mo Prepartum	At Parturition	Lactation 2 wk	Lactation 1 mo	Lactation 2 mo	Lactation 3 mo
				Cows				
Plasma Vit. A								
	I	24.9	8.3	11.3	11.1	10.1	14.2	13.3
	II	22.5	8.7	15.1	18.3	18.7	15.7	24.2
	III	22.3	10.1	16.3	20.5	14.6	15.0	15.1
	IV	21.1	14.2	16.3	17.7	21.4	21.8	23.5
Plasma Carotene								
	I	40.3	11.6	11.8	8.8	6.0	5.4	12.0
	II	45.8	12.9	10.3	52.6	34.5	31.2	43.0
	III	46.6	31.1	23.4	15.7	13.1	11.1	13.0
	IV	35.2	25.8	24.5	87.8	54.8	36.8	46.7
Milk and Colostrum Vit. A	I			45.6	4.9	4.1	3.3	2.8
	II			72.6	12.6	4.6	2.3	5.4
	III			163.9	4.4	2.5	3.6	3.2
	IV			90.6	7.7	4.0	7.7	4.5
				Calves				
Plasma Vit. A								
	I			3.1	6.2	6.0	6.0	4.1
	II			1.3	9.3	5.7	8.1	9.7
	III			3.6	6.8	5.0	6.3	6.7
	IV			4.1	14.4	6.2	8.0	11.9

parturition. It is recognized that the amounts of carotene administered in these studies are distinctly less than those fed by Fountain et al. (1948), or the vitamin A fed by Speilman et al. (1946a), or by Eaton et al. (1949). This may account for failure to observe substantial placental transfer of vitamin A. These findings are in agreement with those reported by Thomas et al. (1947) who found only small amounts of vitamin A in the livers of newborn kids whose dams had been fed natural rations containing the recommended allowance of carotene for the goat. The vitamin A content of the livers of the calves at three months of age appeared to be affected more by the carotene intake of the dam during lactation than by her liver stores at parturition. The higher liver stores of the cows are reflected in an increase in the liver vitamin A of the calves at three months of age. Examination of the plasma vitamin A levels of the calves reveals a similar trend. It will be noted that there was an actual decrease in the vitamin A stores in the livers of calves of Lot I from birth to three months of age.

The plasma carotene levels of the cows reflected carotene supplementation, but in no case do the average values approach those commonly encountered when cattle are grazing winter range, or consuming good quality roughage (Long et al. 1952). At the beginning of the experimental period, plasma vitamin A content was normal. By mid-gestation, all animals showed a decline to levels usually considered indicative of a low plane of carotene or vitamin A nutrition. Following parturition, the animals receiving supplemental carotene showed normal values for plasma vitamin A, a finding consistent with the increase in liver vitamin A stores in these animals.

The vitamin A content of colostrum was somewhat higher for cows

receiving supplemental carotene during gestation than for those that did not. Substantial amounts of this vitamin were found in the colostrum of cows receiving the low-carotene ration. It is evident that the cow is able to mobilize her liver reserves to produce a colostrum relatively high in vitamin A. As has been previously reported by Van Arsdell and associates (1950), the vitamin A content of the milk repidly declined and remained fairly constant during the second and third months of lactation. Milk vitamin A was generally related to carotene supplementation during the lactation period, while the effect of supplementation during gestation and liver vitamin A stores at parturition was less apparent.

One calf in Lot I (No. 46) developed symptoms of vitamin A deficiency at about three months of age. After the termination of the experimental period, this calf responded to the administration of 480,000 I. U. of vitamin A. None of the cows in this experiment showed symptoms of vitamin A deficiency at any time.

EXPERIMENT II

Experimental Procedure

In November, 1952, twenty two-year-old Hereford cows, similar to those used in Experiment I, were selected for use in this study. However, the cows used in this study had all calved in the range herd at approximately 2 years of age and had nursed calves on native grass pastures during the summer. All the cows were in the fourth and fifth months of pregnancy as determined by examination. They were divided into four lots of five cows each on the basis of body weight and expected calving date. The experimental treatments of the cows in each lot were: lot I, no supplemental carotene; lot II, supplemental carotene during

lactation; lot III, supplemental carotene during gestation, and lot IV, supplemental carotene during both gestation and lactation. The basal ration fed each cow during gestation was cottonseed meal, 2½ pounds; ground milo, 1 pound; and wheat straw, ad libitum. During lactation the daily cottonseed meal allowance was increased to three pounds and the ground milo to four pounds. Salt and mineral mixture of equal parts of ground limestone, steamed bone meal, and salt were available to the cows at all times during gestation and lactation. The carotene concentrate (described in Experiment I) was mixed with the grain ration in amounts necessary to provide 60 milligrams of carotene per head daily during gestation and 300 milligrams during lactation.

Liver, blood and milk samples were collected periodically from the cows and calves using the same time schedule and procedure described in Experiment I. Analyses were made for vitamin A and carotene using the same methods as previously cited.

Results and Discussion

The average liver levels of vitamin A and carotene for the four lots of cows and their calves are presented in Table 4. A summary of the plasma and milk levels of vitamin A and carotene for the cows and of plasma composition for the calves is shown in Table 5. The data for individual animals of which this is the summation are given in Tables 14 through 20, appendix.

Initial liver stores of vitamin A and carotene of the cows were high, reflecting high carotene intake during the summer grazing season. That vitamin A liver reserves of cows grazing green pasture are quite variable is indicated by the range of from 62 to 462 micrograms of

TABLE 4

Average Vit. A and Carotene Content of Livers of Cows and Their Calves (Mcg/gm Dry Matter)

	Lot No.	5 mo. Prepartum	At Parturition	3 mo. Post Partum
		Cows		
Liver Vit. A				
	I	302.9	141.3	31.4
	II	307.6	138.4	129.6
	III	151.2	56.3	9.7
	IV	251.7	112.3	85.7
Liver Carotene				
	I	20.2	4.7	2.5
	II	18.7	5.3	11.1
	III	11.6	5.7	1.8
	IV	17.3	6.9	9.8
		Calves		
Liver Vit. A				
	I		3.9	3.3
	II		5.7	19.6
	III		2.7	1.7
	IV		4.9	11.8
Liver Carotene				
	I		0.9	0.8
	II		2.0	0.7
	III		1.4	0.4
	IV		1.3	1.2

vitamin A per gram of dry matter for the cows in this experiment. During gestation, the liver stores of all cows decreased rapidly with one exception, this being a cow which had less than average liver reserves and to which dietary carotene was fed. Supplementation of the rations of the cows of Lots III and IV with 60 milligrams of carotene per head daily did not retard the rate of depletion of the liver stores of

TABLE 5

Average Vit. A and Carotene Content of Plasma and Milk of Cows and Vit. A Content of Plasma of Calves (Mcg/100 ml)

	Lot No.	5 mo. Prepar-tum	1 mo. Prepar-tum	At Partu-rition	Lactation 1 wk.	2 wk.	1 mo.	2 mo.	3 mo.
				Cows					
Plasma Vit. A									
	I	32.5	25.0	17.3	14.4	17.0	17.2	18.6	15.5
	II	30.0	21.1	12.2	14.3	17.9	15.6	15.4	26.5
	III	27.4	20.9	13.4	12.2	12.6	12.5	12.1	16.9
	IV	34.0	25.5	16.8	12.3	17.1	19.6	22.8	30.4
Plasma Carotene									
	I	111.6	22.9	21.3	19.8	21.2	20.8	18.4	18.6
	II	102.9	21.6	17.5	89.4	127.5	147.9	149.1	151.7
	III	73.8	41.4	48.1	28.1	26.9	23.3	17.2	19.5
	IV	97.5	49.1	63.0	89.6	113.2	101.1	117.0	92.3
Milk and Colos-trum Vit. A	I			144.0	6.2	5.3	6.2	6.3	3.8
	II			224.5	11.0	7.8	9.0	8.8	9.9
	III			128.3	6.5	5.7	3.8	3.7	3.3
	IV			133.2	10.0	7.8	7.6	6.6	5.8
				Calves					
Plasma Vit. A									
	I			4.9	13.2	11.6	7.9	6.0	4.5
	II			3.8	12.0	11.5	9.5	9.0	12.6
	III			6.2	8.6	7.3	5.9	4.6	5.6
	IV			4.9	13.6	13.8	10.3	10.0	11.5

vitamin A significantly. However, the addition of 300 milligrams to the daily ration during lactation (Lots II and IV) did tend to spare liver stores of vitamin A and actually increased the liver levels of carotene. Cows that received no supplemental carotene during lactation (Lots I and III) showed a continued and accelerated decrease in vitamin A liver stores.

Liver stores of vitamin A and carotene of the newborn calves did not appear to be related to treatment of the cows during gestation or to their liver stores at parturition. These results are in agreement with those observed in Experiment I and with those reported by Thomas et al. (1947), and Guilbert and Hart (1935). It is apparent from the reports of Braun and Carle (1943), Spielman et al. (1948), and Eaton et al. (1949) that extremely high intakes of carotene or vitamin A are necessary before substantial placental transfer occurs. Supplementation of the rations of the cows during lactation (Lots II and IV vs. Lots I and III) produced a rather marked increase in the calves' liver stores of vitamin A at three months of age. Examination of the individual data of the cows and calves shows that the liver reserves of the cows also exert an effect on the liver stores of the calves at three months of age; however, this effect is much less apparent than that of the carotene intake of the cow during lactation. The plasma vitamin A levels of the calves (Table 5) from one to three months of age show a similar response to the carotene intake of their dams during lactation, whereas during the first two weeks no such effect was observed.

The plasma carotene levels of the cows at the beginning of the experiment were indicative of the previous high carotene intake. The effect of carotene supplementation on the plasma carotene levels was

not apparent until the third month of the experimental period. During lactation the plasma carotene levels of the cows receiving supplemental carotene were comparable to those reported by Long et al. (1950) for cows receiving a good quality roughage. Plasma vitamin A levels of the cows were essentially normal in all lots until the latter stages of the lactation phase. By the end of the third month of lactation the cows not receiving supplemental carotene had lower plasma vitamin A levels than those receiving additional carotene. The normal plasma vitamin A levels of the cows of Lots II and IV, in spite of declining liver stores, and the normal reproduction and lactation performances of these two lots of cows demonstrate that it is not necessary to maintain high liver vitamin A reserves in order to meet the daily carotene requirement.

The vitamin A content of the colostrum of the cows of this study was considerably higher than that observed in Experiment I, suggesting that the higher liver stores of the cows used in this study may have been responsible for this effect. However, no effect of the vitamin A reserves of the cow on the vitamin A content of the colostrum was apparent in this study. It appears that the liver stores must be quite low before the colostrum vitamin A content is affected. The carotene content of the colostrum was higher for those cows which received supplemental carotene during gestation. Milk levels of vitamin A were directly related to carotene supplementation during lactation.

Typical symptoms of avitaminosis A (Guilbert and Hart, 1935) were observed in three calves (33, 42, and 57) of Lot III and two calves (44 and 65) of Lot I. Calves 42 and 65 died between two and three months of age. Another calf (14) of Lot I died at one week of age due to the combined effects of navel and respiratory infections. No

symptoms indicative of a vitamin A deficiency were observed during this experiment in any of the cows, regardless of treatment, nor in the calves of Lots II and IV.

These findings suggest that mobilization of stored vitamin A and carotene by the lactating beef cow on a low plane of carotene intake is insufficient to maintain normal vitamin A levels in the tissues of their nursing calves. Milk vitamin A, and to a lesser degree milk carotene, seem much more closely related to dietary carotene during lactation than to previous treatment resulting in differential liver stores.

PART III

THE REPRODUCTION AND LACTATION PERFORMANCE OF BEEF COWS FED LOW-CAROTENE RATIONS

During periods of drouth or in cold climates it is sometimes necessary for beef cows to be maintained for long periods of time on dry feed. Under such conditions, good quality roughage is often very scarce and expensive. Since poor quality roughage, properly supplemented, can be utilized advantageously by ruminants, this experiment was designed to determine the importance of carotene in such a ration for beef cows.

Experimental Procedure

This experiment was a continuation of a study initiated by Van Arsdell (1951). On October 19, 1950, four weanling Hereford heifer calves were selected from the experimental herd and placed in dry lot at the experimental feeding barn. These heifers have been maintained since that time on concrete pens and special precautions have been taken to prevent them from obtaining green feed.

The rations fed have varied somewhat with the supply of feeds available and the stage of growth, pregnancy or lactation of the heifers. Cottonseed cake or meal, oats, milo and dried beet pulp have been used as concentrates. Wheat straw has been used as the roughage, except for a short period (March 10 to June 20, 1952) when it was necessary to use weathered range grass, baled in February, 1952, as the roughage.

Roughage has been fed ad libitum throughout the study, and the concentrate mixture was fed once daily. Salt and a mineral mixture of equal

parts of steamed bonemeal, ground limestone and salt have been available to the cattle at all times. The rations were formulated to meet the National Research Council's recommended allowances for digestible protein, T. D. N., and minerals at each stage of the experiment, i. e., growth, pregnancy or lactation.

The heifers were exposed to a bull during July and August of 1951 and conceived readily. After completing approximately three months of lactation with their first calves, they were exposed again in August, 1952, and all conceived again.

Blood and liver biopsy samples were taken monthly for the first 8 months of the experiment. The data obtained have been presented by Van Arsdell (1951). Additional liver samples were collected in November, 1951, at each parturition and at six months post-partum. Liver samples were collected from the first calves at birth and six months of age. Blood samples from the cows and calves were collected at monthly intervals during the experiment. Milk samples were collected periodically during lactation. In obtaining milk samples, the calf was removed from the cow for about 6 hours prior to taking the sample and one quarter of the cow's udder was milked completely. The blood, liver, and milk samples were analyzed for carotene and vitamin A. Liver samples were analyzed according to the method of Gallup and Hoefer (1946), plasma by the method of Kimble (1939) and milk by the method of Lesher et al. (1945).

Results and Discussion

The vitamin A and carotene contents of representative plasma and liver samples of these cows are presented in Table 6. Complete individual

TABLE 6

Vitamin A and Carotene Contents of Plasma and Vitamin A Contents of Livers of Cows Fed Low-Carotene Rations for 32 Months

Cow No.	1951 Nov.	1952 June	1952 Nov.	1952 April	1953 Jan.	1953 May	1953 July
			Plasma Vitamin A (Mcg/100 ml)				
11	29.8	27.1	28.3	3.9	14.6	7.3	4.4
15	22.3	26.9	46.7	3.8	15.9	4.0	7.8
18	18.0	17.2	29.1	4.1	19.9	4.2	2.4
33	17.1	22.8	32.0	4.7	16.4	2.9	1.2
			Plasma Carotene (Mcg/100 ml)				
11	65.0	21.0	17.1	18.4	12.6	16.8	10.0
15	82.0	16.0	23.3	30.0	17.4	14.4	19.5
18	94.0	28.0	47.3	18.9	16.2	12.0	12.0
33	85.0	26.0	33.9	33.0	18.0	11.1	9.9
			Liver Vitamin A (Mcg/gram Dry Matter)				
11	307.0	32.5	10.0	7.1	2.4	3.7	
15	420.0	122.3	19.6	2.9	4.0	3.6	
18	285.4	11.1	4.5	2.2	2.5	2.1	
33	408.2	68.7	26.1	4.7	4.2	6.8	

data are shown in Tables 21 and 22, appendix. Vitamin A levels of the colostrum and milk from the cows, as well as the plasma and liver levels of the calves, are given in Table 7.

It is apparent from the data presented in Table 6 that the depletion of liver stores of carotene and vitamin A in the cows was quite rapid during the early months of the experiment. As was observed by Frey and Jenson (1946, 1947), the rate of depletion decreased as the experiment progressed and the liver stores were reduced. After 18 months of depletion, the liver vitamin A contents of the cows declined to a very low level (2.2 to 7.1 mcg/gram dry matter) at calving time in April, 1952.

TABLE 7

Vitamin A Content of Colostrum and Milk from Cows Fed Low-Carotene Rations and the Plasma and Liver Vitamin A Levels of Their Calves

Cow No.	First Lactation				Second Lactation	
	At Parturition	1 mo.	3 mo.	6 mo.	At Parturition	1 mo.
	Milk Vitamin A (Mcg/100 ml)					
11	56.5	7.1	4.8	1.5	149.7	2.4
15	95.3	3.1	1.5	4.8	38.8	2.4
18	170.7	4.8	4.8	4.7	49.5	2.9
33	49.5	4.2	2.6		52.3	3.3
	Calves' Plasma Vitamin A (Mcg/100 ml)					
11	0.0	7.6≠	3.8	8.7	4.2	2.6
15*	0.0	7.4	5.3	7.2	0.0	2.9
18*	0.0	4.8	1.0	4.0	1.0	1.0
33*	0.0	2.9	13.3		2.6	2.7
	Calves' Liver Vitamin A (Mcg/gm. Dry Matter)					
11	0.0			23.0		
15*	2.1			14.9		
18*	4.0			5.8		
33*	6.3		40.7**			

*Calves were supplemented with vitamin A when deficiency symptoms were observed.

≠Calf transferred to this cow after death of her calf.

**Calf died of pneumonia 2 days after receiving vitamin A supplement.

In spite of the lactation phase and the second pregnancy period which followed, the liver vitamin A levels were still approximately the same when the second calves were born in May, 1953. No symptoms of a vitamin A deficiency have been observed in any of the cows during the 32 months of this study. These findings are in contrast to those reported by

Guilbert and Hart (1934, 1935) who found that mature cows became deficient after 9 or 10 months on a depletion ration. This experiment has also failed to confirm the results of Jones et al. (1943) that night blindness occurs in heifer and steer calves after three to six months of depletion. The latter workers used conttonseed hulls as the roughage in the depletion ration, while in the studies reported herein, wheat straw was the roughage feed. Although Guilbert and Hart (1934, 1935) and Jones et al. (1943) were unable to measure the initial liver stores of their experimental animals, it seems possible that the vitamin reserves of their animals were not as high as those of the heifers used in this study.

Plasma levels of carotene, as shown in Table 7, decreased during the early months of the experiment and then continued at a level consistent with the low carotene intake. The vitamin A content of the plasma remained at levels considered within the normal range from the start of the experiment to November, 1952, and then declined to levels indicative of a low plane of vitamin A and carotene nutrition. At the time of this report, the plasma vitamin A levels of the cows are comparable to those observed in vitamin A deficient calves. No attempt is made to explain the significance of these low plasma vitamin A levels.

There was no appreciable amount of placental transfer of vitamin A or carotene by these cows as is shown by plasma and liver levels of vitamin A and carotene of the newborn calves. Substantial amounts of vitamin A were found in the colostrum of all cows in both lactation periods; however, the levels were not as high as those obtained with cows fed low-carotene rations during gestation as reported previously in Part II. The vitamin A content of the milk was somewhat lower than

had been previously observed in cows receiving adequate carotene during lactation.

The calves produced by these cows both years were normal at birth and only one retained placenta (second parturition for cow 33) was observed. However, this retained placenta could not be attributed directly to the lack of vitamin A. No other abnormalities in the reproductive performance of the cows was detected.

Symptoms typical of avitaminosis A described by Guilbert and Hart (1935) was observed in the first calves of these cows early in the nursing period. Calf 11 died with a severe case of diarrhea at one week of age. Another calf of similar breeding that had nursed its dam for three days in the experiment range herd was transferred to this cow. This "transfer calf" nursed cow 11 for seven months without exhibiting deficiency symptoms. A liver sample taken at 6 months of age indicated that substantial stores of vitamin A were still present. The other three calves developed deficiency symptoms between 3 and 5 weeks of age. These calves were maintained throughout the seven-month period by administration of large doses of vitamin A each time the symptoms recurred. Halibut liver oil was given by capsule in amounts sufficient to supply 480,000 I. U. of vitamin A in each treatment.

The second calves produced by these cows remained normal for approximately two weeks after birth and then began to show signs of the lack of vitamin A. Intermittent diarrhea, incoordination, lacrimation and impaired vision were observed in all the calves by the time they were six weeks of age.

The cows in this study exhibited a remarkable ability to maintain

themselves when fed a low-carotene ration for a long period of time. However, the output of vitamin A in the milk was not sufficient to protect the calves from a vitamin A deficiency. It is apparent that the first two months after birth is the critical period in the vitamin A nutrition of the beef calf. This fact is significant in the management of the beef cow and calf herd in a late fall or winter calving program in Oklahoma.

SUMMARY

Studies were conducted with beef cattle to determine (I) the effect of the level of carotene intake on the utilization of dietary carotene, (II) the relative importance of dietary carotene and liver stores of carotene and vitamin A during reproduction and lactation, and (III) the effect of low-carotene rations on reproduction and lactation.

The apparent utilization of dietary carotene as measured by digestion trials with steers was not affected by increasing the intake from four to thirty-two times the minimum daily requirement. A relatively constant percent of the dietary carotene was excreted at all levels of intake.

Beef cows receiving 60 milligrams of carotene per head daily were unable to maintain liver stores of vitamin A during gestation. Increasing the carotene intake to 300 milligrams during lactation had a sparing effect on the liver vitamin A reserves. Vitamin A in the plasma and the liver of the calves was closely associated with the carotene intake of the dam during lactation, but was also influenced by the liver stores of the cow at parturition.

Four cows fed a low-carotene ration for 32 months exhibited a remarkable ability to maintain themselves. However, the output of vitamin A in the milk was not sufficient to protect their calves from avitaminosis A. Eight calves produced by these cows during the study developed symptoms typical of a vitamin A deficiency between one and six weeks of age.

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APPENDIX

TABLE 8

Vitamin A and Carotene Contents of Plasma of Cows During Gestation Phase of Experiment I (Part II) (Mcg/100 ml)

Cow No.	4-3-52		5-5-52		6-3-52		7-25-52		9-3-52	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.
					Lot I					
18	29.7	44.0	9.2	22.5	14.2	16.8	6.9	9.9	7.8	6.6
46	20.1	36.7	6.1	21.9	11.7	18.3	9.7	15.0	3.9	12.9
Av.	24.9	40.3	7.7	22.1	13.0	17.6	8.3	12.5	5.9	9.8
					Lot II					
12	23.8	38.7	12.2	25.5	18.9	16.8	10.4	12.1	12.6	8.1
38	22.8	60.3	11.4	23.4	13.0	18.9	9.5	11.7	8.3	11.1
47	20.9	38.4	6.2	13.5	18.3	19.8	6.3	15.9	4.9	7.8
Av.	22.5	45.8	9.9	20.8	16.7	18.8	8.7	13.2	8.6	9.0
					Lot III					
2	21.8	45.0	9.8	21.9	14.5	18.3	9.9	32.4	15.1	37.5
7	24.2	38.4	13.1	19.2	12.4	16.8	11.8	37.5	18.0	37.5
70	21.4	56.4	9.6	18.3	21.3	17.7	8.6	23.4	13.4	34.5
Av.	22.5	46.6	10.8	19.8	16.1	17.6	10.1	31.1	15.5	36.5
					Lot IV					
58	16.8	30.7	8.1	15.6	13.5	13.2	11.6	26.7	8.2	27.9
64	25.5	39.5	8.9	20.1	15.8	14.1	14.0	23.2	17.2	34.5
Av.	21.2	35.1	8.5	17.9	14.7	13.7	12.8	25.0	12.7	31.2

TABLE 9

Vitamin A and Carotene Contents of Plasma of the Cows in Experiment I (Part II) During Lactation (Mcg/100 ml)

Cow No.	Parturition		2 wk.		1 mo.		2 mo.		3 mo.	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.
					Lot I					
18	16.4	11.0	9.0	8.7	12.3	5.4	14.2	5.4	14.7	12.0
46	6.2	12.6	13.2	9.0	7.8	6.6	14.2	5.4	11.8	12.0
Av.	11.3	11.8	11.1	8.8	10.2	6.0	14.2	5.4	13.3	12.0
					Lot II					
12	14.0	10.8	20.6	47.1	16.6	30.0	19.9	38.4	23.9	44.4
38	16.5	9.0	18.1	41.4	23.8	39.0	11.4	23.7	22.9	38.4
47	14.7	11.1	16.1	69.0	15.6	34.5	15.8	31.5	25.7	46.2
Av.	15.1	10.3	18.3	52.6	18.7	34.5	15.7	31.2	24.2	43.0
					Lot III					
2	21.6	33.0	25.2	17.4	12.2	14.4	16.7	10.2	16.9	15.0
7	11.0	20.1	21.3	17.7	18.9	16.8	13.6	12.0	14.7	11.4
70	16.3	18.0	15.0	12.0	12.6	8.1	14.7	11.1	13.7	12.6
Av.	16.3	23.4	20.5	15.7	14.6	13.1	15.0	11.1	15.1	13.0
					Lot IV					
58	15.2	23.4	17.2	81.0	21.8	52.5	19.1	31.5	21.7	46.2
64	17.4	25.5	18.2	94.5	20.9	57.0	24.5	42.0	26.2	47.1
Av.	16.3	24.5	17.7	87.8	21.4	54.8	21.8	36.8	23.5	46.7

TABLE 10

Vitamin A and Carotene Contents of the Livers
Of the Cows in Experiment I (Part II)
(Mcg/gram of Dry Matter)

Cow No.	6 mo. Prepartum		Parturition		3 mo. Post-partum	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car
			Lot I			
18	81.2	5.0	6.7	2.4	1.7	1.2
46	56.6	3.0	4.6	2.1	1.6	1.0
Av.	68.9	4.0	5.7	2.3	1.7	1.1
			Lot II			
12	90.3	7.1	13.3	2.6	25.7	4.4
38	62.6	4.0	7.1	2.1	6.5	2.4
47	58.8	3.0	7.9	3.3	24.6	4.2
Av.	70.6	4.4	9.4	2.7	18.9	3.7
			Lot III			
2	123.0	5.8	20.9	3.0	13.5	2.0
7	102.3	4.6	18.2	2.6	5.3	2.8
70	142.7	7.2	22.6	2.0	3.9	1.9
Av.	122.7	5.9	20.6	2.5	7.6	2.2
			Lot IV			
58	92.2	3.5	12.7	3.7	19.0	5.1
64	92.1	8.0	16.0	3.2	27.9	5.3
Av.	92.1	5.8	14.3	3.5	23.5	5.2

TABLE 11

Vitamin A and Carotene Contents of Plasma of Calves in Experiment I (Part II) (Mcg/100 ml)

Calf No.	Birth		2 wks.		1 mo.		2 mo.		3 mo.	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.
					Lot I					
18	6.1	0.0	5.8	0.0	11.0	4.5	8.9	5.1	4.1	4.2
46	0.0	1.8	6.6	0.0	1.1	0.0	3.2	4.5	4.0	3.6
Av.	3.0	0.9	6.2	0.0	6.0	2.2	6.0	4.8	4.1	3.9
					Lot II					
12	0.5	0.0	8.3	11.7	calf died from injury					
38	1.3	0.0	9.4	1.8	7.6	6.9	7.2	5.1	9.5	5.1
47	2.2	0.3	10.3	5.1	3.8	0.0	9.1	5.1	9.9	4.8
Av.	1.3	0.1	9.3	6.2	5.7	3.5	8.1	5.1	9.7	4.9
					Lot III					
2	7.4	0.0	5.2	2.4	2.5	0.0	5.9	5.1	6.4	4.2
7	1.1	1.8	6.6	7.8	7.4	2.4	4.9	3.0	5.7	1.8
70	2.2	0.6	8.7	4.5	5.0	1.8	8.1	6.6	6.9	3.0
Av.	3.6	0.8	6.8	4.9	5.0	1.4	6.3	4.9	6.3	3.0
					Lot IV					
58	3.0	1.8	17.4	3.6	5.0	1.8	8.5	5.1	11.4	4.8
64	5.2	1.2	11.4	5.1	7.4	2.4	7.5	10.2	12.4	11.4
Av.	4.1	1.5	14.4	4.4	6.2	2.1	8.0	7.6	11.9	8.1

TABLE 12

Vitamin A and Carotene Contents of the Livers
Of Calves in Experiment I (Part II)
(Mcg/gram of Dry Matter)

Calf No.	Birth		3 months	
	Vit.A	Car.	Vit.A	Car.
		Lot I		
18	4.2	4.3	1.9	1.2
46	4.1	4.4	1.8	1.4
Av.	4.2	4.4	1.9	1.3
		Lot II		
12	3.5	1.5		
38	2.3	2.4	9.2	1.5
47	4.4	3.2	19.3	1.0
Av.	3.4	2.6	14.3	1.3
		Lot III		
2	2.2	4.6	8.2	2.0
7	2.8	2.0	3.9	1.9
70	2.9	0.0	3.2	3.2
Av.	2.6	2.2	5.1	2.6
		Lot IV		
58	2.8	2.8	18.6	0.6
64	3.2	1.2	26.0	4.2
Av.	3.0	2.0	22.3	2.3

TABLE 13

Vitamin A Content of Colostrum and Milk from Cows of Experiment I (Part II) (Mcg/100 ml)

Cow No.	Partu-rition	2 da.	4 da.	7 da.	14 da.	21 da.	1 mo.	2 mo.	3 mo.
				Lot I					
18	61.1	40.9	27.8	10.8	6.0	7.5	6.0	2.1	3.3
46	28.1	20.4	14.3	9.6	3.8	4.5	2.2	4.5	2.3
Av.	44.6	30.7	21.1	10.2	4.9	6.0	4.1	3.3	2.8
				Lot II					
12	57.4	60.8	10.5	6.8	17.3	5.3	2.3	2.4	6.3
38	61.9	12.0	7.5	15.8	15.0	5.7	8.0	1.8	6.8
47	98.6	12.0	5.0	13.3	5.4	4.5	3.5	2.7	3.0
Av.	72.6	28.3	7.7	12.0	12.6	5.2	4.6	2.3	5.4
				Lot III					
2	71.3	11.6	18.0	5.4	6.9	13.2	3.0	4.1	3.0
7	256.5	32.3	11.7	10.5	3.3	1.5	1.5	2.9	3.8
70	163.9	18.8	26.3	13.5	3.0	6.0	3.0	3.8	2.7
Av.	163.9	20.9	18.7	9.8	4.4	6.9	2.5	3.6	3.2
				Lot IV					
58	99.4	33.0	8.7	4.5	6.3	5.7	4.5	5.7	4.5
64	81.8	6.8	8.0	15.8	9.0	3.0	3.5	9.8	4.5
Av.	90.6	19.9	8.3	10.1	7.7	4.4	4.0	7.7	4.5

TABLE 14

Vitamin A and Carotene Content of Plasma of Cows During the Gestation Phase of Experiment II (Part II) (Mcg/100 ml)

Cow No.	Nov. 12		Dec. 20		Jan. 31		Feb. 28	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.
				Lot I				
14	27.9	102.0	24.8	31.5	22.4	24.0	23.1	27.0
24	35.0	93.0	25.6	27.6	21.8	16.8	24.6	21.3
31	31.2	153.0	29.9	42.0	22.4	23.4	30.5	25.2
44	33.6	120.0	28.1	35.4	17.7	19.5	25.4	24.3
65	34.8	90.0	33.9	20.4	19.6	10.8	21.4	16.8
Av.	32.5	111.6	28.5	31.4	20.8	18.9	25.0	22.9
				Lot II				
17	32.9	153.0	19.4	30.0	18.4	30.9	20.2	33.9
22	27.7	90.0	19.1	27.0	12.6	14.4	19.8	18.0
25	30.5	60.0	24.5	21.9	18.5	12.0	25.6	14.4
52	30.7	51.0	30.1	24.0	20.9	16.8	21.4	17.4
67	28.1	160.5	22.1	42.0	18.6	19.5	18.3	24.3
Av.	30.0	102.9	23.0	29.0	17.8	18.7	21.1	21.6
				Lot III				
33	23.9	78.0	21.6	32.4	19.6	27.6	19.4	57.0
34	30.2	78.0	22.5	35.4	14.5	24.0		
42	28.0	78.0	20.6	27.0	12.7	16.2	19.4	34.4
51	26.1	69.0	24.5	27.6	19.5	21.0	21.7	33.0
57	28.6	66.0	23.2	25.5	20.4	22.8	23.0	41.1
Av.	27.4	73.8	22.5	29.6	17.3	22.3	20.9	41.4
				Lot IV				
3	25.5	63.0	25.2	34.2	32.7	39.9	22.3	45.0
19	39.2	144.0	30.7	45.0	36.4	31.5	22.1	54.0
20	35.9	90.0	29.0	37.5	21.9	30.0	25.6	48.0
29	31.4	90.0	27.1	35.4	25.3	31.5	24.4	44.4
50	38.0	100.5	29.2	34.2	28.5	24.9	33.1	54.0
Av.	34.0	97.5	28.2	37.3	29.0	31.6	25.5	49.1

TABLE 15

Vitamin A and Carotene Contents of Plasma of Cows During the Lactation Phase of Experiment II (Part II) (Mcg/100 ml)

Cow No.	Parturition		1 week		2 weeks		1 month		2 months		3 months	
	Vit.A	Car	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.
						Lot I						
14	14.7	21.3	10.7	23.4	23.5	21.3	18.9	19.5	17.4	18.0	13.5	12.0
24	23.6	20.1	20.7	13.2	15.7	20.4	14.9	18.0	28.4	25.2	20.7	26.1
31	20.6	27.0	19.9	22.5	15.6	21.3	18.3	24.3	15.7	14.4	13.9	19.5
44	10.9	20.1	8.4	22.5	12.1	23.4	9.3	18.0	6.4	19.5	9.8	17.4
65	16.9	18.0	12.1	17.4	18.2	19.5	24.4	24.3	25.0	15.0	19.8	18.0
Av.	17.3	21.3	14.4	19.8	17.0	21.2	17.2	20.8	18.6	18.4	15.5	18.6
						Lot II						
17	14.5	23.8	17.6	93.0	19.1	114.0	18.9	164.4	21.2	147.9	15.2	140.1
25	13.5	11.1	11.2	33.0	18.9	84.0	12.3	91.5	12.6	93.0		
52	12.7	13.2	14.0	102.6	16.9	123.0	14.4	129.0	12.8	144.0	32.4	108.0
67	8.2	21.9	14.4	129.0	16.7	189.0	16.8	207.0	14.9	211.5	31.9	207.0
Av.	12.2	17.5	14.3	89.4	17.9	127.5	15.6	147.9	15.4	149.1	26.5	151.7
						Lot III						
33	10.4	52.5	10.4	30.9	12.5	49.2	14.5	36.9	17.3	25.4	18.1	21.8
34	12.7	21.9	12.5	17.7	11.6	23.4	10.2	18.3	12.1	17.4	18.5	28.5
42	13.6	42.0	11.1	18.0	9.0	15.0	11.4	14.4	13.5	12.0		
51	15.8	57.0	14.4	31.5	13.9	15.6	11.0	18.6	9.2	13.2	14.5	13.2
57	13.7	66.9	12.6	45.0	16.3	31.5	15.6	28.5	8.3	18.0	16.4	14.4
av.	13.4	48.1	12.2	28.6	12.6	26.9	12.5	23.3	12.1	17.2	16.9	19.5
						Lot IV						
3	15.1	49.5	10.4	111.0	16.1	106.5	15.6	108.0	18.9	84.0	26.6	78.0
19	14.2	54.0	10.1	61.5	9.1	112.6	17.9	125.4	19.2	120.0	36.6	96.0
20	18.2	73.5	15.4	78.0	19.9	90.9	19.9	103.5	26.3	93.0	28.7	105.0
29	21.8	58.5	14.1	106.5	18.3	117.0	17.3	127.5	21.2	147.9	29.8	90.0
50	14.6	79.5	11.7	91.5	21.9	140.1	27.1	141.0	28.5	140.1		
Av.	16.8	63.0	12.3	89.6	17.1	113.2	19.6	101.1	22.8	117.0	30.4	92.3

TABLE 16

Vitamin A and Carotene Contents of the Livers
Of the Cows in Experiment II (Part II)
(Mcg/gram of Dry Matter)

Cow No.	5 mo. Prepartum		Parturition		3 mo. Post Partum	
	Vit.A.	Car.	Vit.A	Car.	Vit.A	Car.
			Lot I			
14	284.8	12.0	109.4	2.0	11.4	1.4
24	449.2	22.9	233.9	9.8	75.7	5.9
31	350.7	24.5	132.0	5.3	19.9	3.7
44	112.8	24.9	36.2	2.7	4.4	0
65	317.0	16.7	195.2	3.7	45.8	1.5
Av.	302.9	20.2	141.3	4.7	31.4	2.5
			Lot II			
17	462.5	23.5	307.0	7.7	185.3	14.0
22	170.9	17.2	41.2	5.8		
25	277.6	13.0	69.7	3.0		
52	336.2	21.1	168.8	5.1	146.5	12.5
67	290.6	18.5	105.5	4.8	57.0	6.6
Av.	307.6	18.7	138.4	5.3	129.6	11.1
			Lot III			
33	64.4	9.8	35.7	6.0	4.8	2.3
34	113.8	9.1	63.5	3.9	5.2	2.7
42	192.7	17.3	50.5	6.3		
51	251.2	13.6	84.5	3.9	26.6	1.7
57	134.0	8.5	45.5	8.6	2.1	0.3
Av.	151.2	11.6	56.3	5.7	9.7	1.8
			Lot IV			
3	160.1	13.2	58.9	4.5	29.9	8.4
19	458.4	19.0	210.1	7.9	122.0	6.9
20	62.0	15.0	83.5	6.6	46.6	7.7
29	288.2	21.6	119.6	9.1	144.3	16.4
50	289.7	17.7	92.4	6.6		
Av.	251.7	17.3	112.3	6.9	85.7	9.8

TABLE 17

Vitamin A and Carotene Content of Plasma of Calves of Experiment II (Part II) (Mcg/100 ml)

Calf No.	Birth		1 week		2 weeks		1 month		2 months		3 month	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car	Vit.A	Car	Vit.A	Car.
						Lot 1						
14	4.1	3.0										
24	5.4	4.2	17.0	4.5	15.1	4.5	10.7	6.0	7.2	1.5	2.7	8.1
31	4.3	5.4	14.8	6.6	15.1	0.0	9.6	7.5	6.7	4.5	7.2	8.3
44	5.4	4.2	7.1	4.5	7.2	8.1	6.6	6.3	2.3	3.6	4.3	9.9
65	4.4	1.0	14.0	5.4	9.0	8.1	4.9	2.4	7.8	2.4		
Av.	4.9	3.6	13.2	5.2	11.6	5.1	7.9	5.5	6.0	3.0	4.5	8.8
						Lot II						
17	2.5	3.0	14.8	7.5	13.0	18.0	9.1	7.5	9.7	12.0	7.7	20.4
25	6.1	1.8	6.5	1.8	8.4	1.8	8.7	2.4	7.7	3.3		
52	4.6	2.4	14.7	8.1	10.4	18.0	8.1	8.1	8.8	6.3	15.7	11.1
67	2.2	0.6	11.9	7.5	14.4	14.4	12.3	14.4	9.8	11.1	14.4	24.4
Av.	3.8	1.9	12.0	6.2	11.5	13.0	9.5	8.1	9.0	8.2	12.6	18.6
						Lot III						
33	3.6	3.6	5.1	6.6	6.4	6.6	6.3	4.2	5.7	1.0	6.5	10.1
34	9.0	0.0	11.1	3.0	11.2	3.6	6.2	2.1	6.0	6.6	4.9	8.1
42	4.2	12.0	11.0	6.6	3.9	9.0	6.0	2.4	2.5	1.2		
51	12.1	5.4	7.3	5.4	6.7	4.5	7.3	6.6	4.3	5.4	6.9	13.2
57	2.5	1.8	8.6	8.1	8.1	8.1	4.0	0.0	4.3	5.4	4.9	3.6
Av.	6.2	4.6	8.6	5.9	7.3	6.4	5.9	3.1	4.6	3.9	5.6	8.7
						Lot IV						
3	6.2	2.4	8.2	9.9	10.6	12.0	8.4	5.4	9.7	12.0	9.0	12.0
19	2.1	1.5	13.7	3.6	14.2	14.4	12.3	14.4	7.7	12.0	12.9	19.5
20	4.0	0.6	10.0	8.1	8.9	8.1	8.8	12.0	9.7	12.0	14.2	11.1
29	6.5	3.6	14.1	9.9	12.5	9.0	9.1	9.9	9.0	8.1	9.8	9.9
50	5.5	3.0	21.8	5.4	23.0	8.1	13.1	5.4	14.0	6.6		
Av.	4.9	2.2	13.6	7.4	13.8	10.3	10.3	9.4	10.0	10.1	11.5	13.1

TABLE 18

Vitamin A and Carotene Contents of the Livers
Of Calves in Experiment II (Part II)
(Mcg/gram of Dry Matter)

Calf No.	Birth		3 months	
	Vit.A	Car.	Vit.A	Car.
		Lot I		
14	2.4	0		
24	4.7	1.5	6.0	1.5
31	2.2	2.6	3.2	0.9
44	3.5	0.7	1.8	0.8
65	6.8	0	*2.3	0
Av.	3.9	0.9	3.3	0.8
		Lot II		
17	8.1	2.1	25.0	1.0
25	4.2	0		
52	8.8	4.1	17.1	1.1
67	2.5	1.9	16.6	0
Av.	5.7	2.0	19.6	0.7
		Lot III		
33	4.1	3.1	1.2	0
34	3.2	1.2	1.2	0.6
42	1.4	0		
51	3.0	0	1.8	1.0
57	1.6	2.6	2.4	0.0
Av.	2.7	1.4	1.7	0.4
		Lot IV		
3	1.5	1.0	5.6	1.0
19	3.5	1.8	11.1	0.7
20	2.0	0.8	8.3	1.2
29	4.1	1.5	22.3	1.9
50	3.6	1.6		
Av.	4.9	1.3	11.8	1.2

*Calf died at $2\frac{1}{2}$ months of age. Sample taken immediately after death.

TABLE 19

Vitamin A Content of Colostrum and Milk from Cows of Experiment II (Part II) (Mcg/100 ml)

Cow No.	Partu-rition	2 da.	4 da.	7 da.	14 da.	21 da.	1 mo.	2 mo.	3 mo.
				Lot I					
14	301.5	12.2	9.7	8.7	8.5	6.4	5.0	6.1	3.4
24	48.8	8.3	7.3	4.7	4.3	7.8	4.5	5.4	4.2
31	84.8	17.4	6.6	4.5	3.6	3.6	5.4	4.7	4.5
44	137.6	9.0	6.1	5.4	4.5	4.3	3.6	5.2	2.9
65	191.5	6.1	6.4	7.8	5.7	11.9	11.7	10.2	
Av.	144.0	10.6	7.2	6.2	5.3	6.8	6.2	6.3	3.8
				Lot II					
17	190.0	15.8	7.8	9.0	5.0	10.0	5.7	8.3	11.7
25	471.6	10.4	8.3	9.2	13.2	6.8	9.2	7.8	
52	158.3	10.2	10.2	13.6	7.1	11.0	8.8	9.0	8.0
67	78.0	13.2	12.9	12.0	5.9	8.2	12.3	10.0	7.8
Av.	224.5	12.4	9.8	11.0	7.8	9.0	9.0	8.8	9.9
				Lot III					
33	197.5	13.2	7.8	1.8	3.3	1.8	3.1	4.7	4.8
34	65.9	7.3	6.4	6.4	5.4	6.1	5.2	1.6	2.2
42	132.4	12.9	10.0	5.0	3.8	3.3	3.1	3.1	
51	136.8	21.5	10.0	11.9	10.9	9.5	4.5	3.6	3.1
57	108.9	10.7	9.7	7.5	5.0	4.8	2.9	5.7	2.9
Av.	128.3	13.1	8.8	6.5	5.7	5.1	3.8	3.7	3.3
				Lot IV					
3	208.9	18.6	14.4	12.6	8.2	9.7	8.0	6.8	5.9
19	58.6	107.1	8.5	6.8	7.8	8.7	7.1	7.0	4.5
20	220.3	19.0	11.7	10.6	6.5	9.6	7.1	6.6	7.8
29	110.0	21.7	16.9	10.4	9.3	7.4	6.2	5.9	4.5
50	68.1	26.1	10.7	9.8	7.1	10.2	9.5	6.8	
Av.	133.2	46.5	12.4	10.0	7.8	9.1	7.6	6.6	5.8

TABLE 20

Carotene Content of Colostrum and Milk from Cows of Experiment II (Part II) (Mcg/100 ml)

Cow No.	Partu-rition	2 da.	4 da.	7 da.	14 da.	21 da.	1 mo.	2 mo.	3 mo.
				Lot I					
14	21.0	1.5	1.2	0.0	0.0	0.0	0.0	0.6	0.9
24	3.0	0.0	0.0	0.0	1.7	3.8	1.0	3.0	0.0
31	1.9	1.7	0.5	1.7	0.2	1.0	1.2	3.0	0.0
44	12.4	1.1	0.2	0.5	0.5	0.9	0.5	0.0	0.0
65	13.8	1.5	3.3	0.2	0.8	1.1	0.3	1.2	
Av.	10.4	1.1	1.0	0.5	0.6	1.4	0.6	1.6	0.2
				Lot II					
17	6.8	0.6	0.3	0.6	2.3	3.8	2.3	3.8	2.4
25	18.0	1.7	1.8	2.0	4.1	0.9	1.7	1.5	
52	9.4	2.7	3.0	7.2	3.0	1.6	1.4	2.2	2.9
67	5.3	2.9	4.0	4.7	3.2	2.6	3.2	2.6	2.4
Av.	9.9	2.0	2.3	3.6	3.2	2.3	2.2	2.5	2.5
				Lot III					
33	37.5	3.0	2.0	1.8	1.8	1.0	1.2	1.2	0.0
34	4.5	0.9	0.9	0.0	0.0	1.2	0.6	0.6	1.7
42	29.2	4.5	4.1	1.7	1.2	1.5	1.1	0.5	
51	28.8	2.4	1.1	0.0	0.0	0.0	0.0	0.5	0.5
57	45.0	3.0	1.8	1.4	1.7	0.5	1.2	0.0	0.0
Av.	29.0	2.8	2.0	1.0	0.9	0.8	0.8	0.6	0.5
				Lot IV					
3	32.6	2.6	0.6	0.6	1.2	2.6	1.6	3.8	3.3
19	7.5	16.5	2.1	2.4	4.1	3.9	4.1	4.1	1.8
20	41.3	6.0	5.0	3.0	1.8	1.6	3.2	2.7	1.8
29	19.5	5.4	1.8	1.6	2.0	0.6	1.4	1.8	1.8
50	11.3	4.7	2.9	3.0	2.4	3.8	2.9	2.4	
Av.	22.2	7.0	2.5	2.1	2.3	2.5	2.6	3.0	2.2

TABLE 21

Vitamin A and Carotene Content of Plasma of Four Cows
Fed Low-Carotene Rations (Part III)
(Mcg/100 ml)

Date	Cow 11		Cow 15		Cow 18		Cow 33	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car	Vit.A	Car.
1950								
Nov.	29.8	65.0	22.3	82.0	18.0	94.0	17.1	85.0
Dec.	39.1	19.5	16.3	33.0	34.3	43.5	30.3	40.5
1951								
Jan.	13.6	12.6	13.5	20.4	21.9	30.0	27.7	27.0
Feb.	39.5	25.0	26.7	27.0	25.2	27.0	25.4	30.0
Mar.	42.5	28.0	20.7	35.0	23.3	26.0		
April	36.3	22.5	16.5	18.0	18.7	27.0	30.5	30.9
May	17.4	14.0	29.6	38.0	20.1	34.0	27.0	29.0
June	27.1	21.0	26.9	16.0	17.2	28.0	22.8	26.0
Nov.	28.3	17.1	46.7	23.3	29.1	47.3	32.0	33.9
Dec.	22.2	27.0	26.9	36.3	18.6	51.6	24.9	34.4
1952								
Jan.	20.5	32.7	23.8	41.1	17.3	52.5	20.4	39.9
Mar.	9.3	24.6	4.2	15.6	10.4	24.3	6.2	24.3
April*	3.9	18.4	3.8	30.0	4.1	18.9	4.7	33.0
May	4.5	36.0	9.8	23.7	3.6	37.1	4.4	15.9
June	11.4	21.9	16.6	23.0	7.6	33.0	4.2	11.1
July	14.8	14.5	10.5	16.2	8.4	18.6	12.0	16.8
Aug.	8.9	5.1	25.4	9.6	6.3	7.8	4.8	5.7
Nov.	17.7	6.6	21.4	10.2	18.1	9.0	11.3	10.2
1953								
Jan.	14.6	12.6	15.9	17.4	19.9	16.2	16.4	18.0
Mar.	12.1	9.9	10.0	14.4	14.2	15.6	18.7	12.0
May*	7.3	16.8	4.0	14.4	4.2	12.0	2.9	11.1
July	4.4	10.0	7.8	19.5	2.4	12.0	1.2	9.9

*Calved.

TABLE 22

Vitamin A and Carotene Content of Livers of Four Cows
Fed Low-Carotene Rations (Part III)

Date	Cow 11		Cow 15		Cow 18		Cow 33	
	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.
1950								
Nov.	307.0	9.9	420.0	16.4	285.4	15.1	408.2	11.7
Dec.	316.0	7.1	459.2	8.8	201.6	7.5	514.2	7.6
1951								
Jan.	238.6	4.9	488.2	6.1	175.5	4.8	376.4	5.2
Feb.	139.1	3.1	259.5	4.0	109.7	3.6	258.1	4.1
Mar.	149.4	5.1	218.4	4.6	104.3	4.6	267.3	5.2
Apr.	84.1	2.7	155.9	3.9	58.4	3.2	207.9	4.0
May	70.2	2.1	145.0	3.6	31.8	2.4	198.5	2.7
June	32.5	1.6	122.3	2.8	11.1	2.0	68.7	2.2
Nov.	10.0	2.8	19.6	3.0	4.5	2.5	26.1	2.5
1952								
Apr.	7.1	0.6	2.9	1.2	2.2	1.2	4.7	0.8
1953								
Jan.	2.4	1.8	4.0	0.8	2.5	2.5	4.2	1.8
May	3.7	0.3	3.6	0.2	2.1	0.5	6.8	0.4

VITA

Frank Hamon Baker
candidate for the degree of
Doctor of Philosophy

Thesis: STUDIES OF THE VITAMIN A AND CAROTENE NUTRITION OF BEEF CATTLE

Major: Animal Nutrition

Biographical:

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Undergraduate Study: He attended grade school at Vera, Oklahoma, and graduated from Vera High School in 1941. In the fall of 1941 he entered the Oklahoma Agricultural and Mechanical College, completing two years of study. In 1946, he re-entered the Oklahoma Agricultural and Mechanical College from which he received the Bachelor of Science degree, with a major in Animal Husbandry, in May, 1947.

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Experiences: The writer entered the United States Army in 1943 and was released from active duty in 1945. From 1947 to 1948 he was county agricultural agent of Delaware County, Oklahoma. From 1948 to 1950 he was veterans' agricultural instructor at Ramona High School, Ramona, Oklahoma.

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