VITAMIN A STUDIES WITH BEEF CATTLE

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TABLE OF CONTENTS

INTRODUCTION

Vitamin A has been a recognized nutrient for cattle since Jones and co-workers (1926) demonstrated that vitamin A was essential for normal growth of calves. Vitamin A, as such, is not a natural plant product, but is formed in the animal body from various plant carotenoids. Many carotenoids which possess vitamin A activity are found widely distributed in natural feeds, however, beta carotene has greater biological activity and is present in larger quantities than other carotenoids in most animal feeds. In general, green leafy plants and yellow seeds or roots are rich sources of carotene. Pasture grasses, likewise, provide ample carotene for cattle during the growing season. Weathered grass or hay, straw, cottonseed hulls and other low quality roughages are not good sources of carotene and if fed for long periods of time must be supplemented with carotene or vitamin A to prevent a deficiency in animals. Well-cured prairie and legume hays, particularly alfalfa, are usually the most economical sources of supplemental carotene for the livestock producer.

Farmers and ranchers in Oklahoma and other southwestern states have frequently reported livestock losses attributed to vitamin A deficiency, particularly during severe drouths or during winter months in herds fed low quality roughages. Although the literature contains many references concerning the carotene and vitamin A nutrition of beef cattle, many questions remain unanswered; therefore, studies of a long-time nature, particularly in regard to needs for reproduction and lactation, have been underway at this station since 1946.

One of the studies reported herein was concerned with the repeatability and precision of a liver biopsy methods used to estimate the

vitamin A content of livers of intact cattle. As a continuation of earlier work, a second phase dealt with the effect of plane of nutrition on depletion of vitamin A reserves during gestation and on carotene requirements during early lactation. A third phase was concerned with the importance of carotene supplementation in steer fattening rations in which milo was the chief concentrate.

REVIEW OF LITERATURE

This review of important work relative to the vitamin A needs of the bovine is divided into two major parts. No attempt is made to cover completely all of the voluminous literature on carotene and vitamin A, since experimental work concerning the metabolism of carotene and vitamin A has been reviewed by Van Arsdell (1952) and that concerned with placental and mammary transfer by Baker (1953). Only those papers pertinent to the studies involved herein have been reviewed.

The Carotene Requirements of Cattle During Gestation and Lactation

Hart and Guilbert (1933) reported the occurrence of vitamin A deficiencies in beef cattle maintained on rations devoid of green feed for several months. Young cattle developed deficiency symptoms earlier than mature cattle. Calves from cows on these rations developed typical symptoms of avitaminosis A as confirmed later by Guilbert and Hart (1934), Moore and Sykes (1940), Schmidt (1941), Ritzman et al. (1945), Helmboldt et al. (1953) and others.

The most common clinical symptoms observed in cattle have been night blindness, excessive lacrimation, ulceration of the cornea, unthrifty appearance, intermittent diarrhea and pulmonary complications. Increased cerebrospinal fluid pressure occurs in both young and mature cattle, accompanied by incoordination. Histological changes likewise occur in areas of the body covered with epithelial tissue. Calves born of depleted cows are apt to be weak at birth and develop diarrhea within a few days. Avitaminosis A is accompanied by a reduced rate of gain or loss in weight and

anasarca in feedlot steers. In pregnant cows, abortions frequently occur, and retention of the placenta has been attributed to avitaminosis A.

Using the onset of night blindness as the criteria for estimating carotene requirements, Guilbert and Hart (1935) estimated the minimum daily requirement of carotene to be between 26 and 33 mcg. per kg. of body weight. At this level, no storage of vitamin A in the liver resulted. They reported that the carotene requirements seemed to be proportional to body weight rather than to energy needs, and that to compensate for low-food consumption per unit of weight, large animals would require a higher percentage of carotene in their ration than small animals. They likewise reported that there was a greater requirement during a period of active growth, and that animals on sub-maintenance rations utilize liver vitamin A less rapidly than those on a super-maintenance and otherwise complete rations.

The carotene requirements of dairy cattle for conception were estimated to be approximately 40 to 45 mcg. per lb. per day by Kuhlman and Gallup (1942). Other investigators have reported some breeding failure in dairy cattle on deficient rations (Schmidt, 1941; Hilton et al., 1941). Studies with beef cattle (Davis and Madsen, 1941; Madsen and Davis, 1949; Baker, 1953; and Church et al., 1955), however, have indicated no appreciable decline in conception rate or breeding efficiency.

Davis and Madsen (1941) found that an intake of less than 60 mcg. of carotene per kg. per day was not sufficient to allow young Hereford or Shorthorn cows to produce normal calves. In a later report, Madsen and Davis (1949) found that over a long period involving several generations that reproduction was satisfactory when cows were given 90 mcg. per kg. (4 mg. per 100 lb.). Van Arsdell et al. (1950) fed Hereford cows carotene at levels of 38, 75 and 106 mg. per day during the last 45 days of gestation

and first 30 days of lactation, and noted no differences in health or vigor of the calves, although blood carotene levels were correlated to the carotene intake. Baker, Pope and MacVicar (1954) reported no reproductive failure in Hereford cows given carotene-low rations alone or supplemented with 60 mg. of carotene per day, and further work by Church et al. (1955) showed that reproductive failure resulted in Hereford cattle only after severe depletion of liver vitamin A stores.

Converse and Meigs (1938), working with dairy cows, suggested that carotene be fed at a level of 80 to 120 mcg. per lb. of body weight during the latter part of the gestation period, while Kuhlman and Gallup (1941) reported that 40 to 45 mcg. per lb. appeared to be about the minimum which would promote normal reproduction and initiation of normal lactation. Kuhlman and Gallup (1941) further state that the requirements for milk production probably do not exceed the requirements for normal reproduction. Schmidt (1941) fed carotene at levels of 1, 2 and 2.5 mg. per 100 lb. to Jersey cattle from five months of age through gestation and lactation. Reproduction and lactation were unsatisfactory at each level. Ronning and co-workers (1953) state that 90 mcg. per lb. appear to be the minimum amount of carotene necessary for satisfactory reproduction in Guernsey cows. Lower levels resulted in premature births, abortions and weak calves. Retained placentas occured frequently on lower levels of carotene intake.

Watkins and Knox (1954) fed range breeding cows supplemental carotene from alfalfa at levels of 8.8 to 27 mg. per cow for one month before calving and levels of 19.6 to 51.7 mg. per cow after calving. The supplemental carotene had no beneficial results and produced no significant differences in blood plasma carotene or vitamin A.

Pierce (1954) provided various levels of carotene to depleted ewes. The results of this trial, in which the ewes were maintained on the same

rations for three years, indicated that 50 mcg. per kg. were necessary for successful reproduction in sheep.

The recommended carotene allowance given by the National Research Council (1950) for wintering pregnant cows is 60 mg. per 1000 lb. of body weight. This recommendation is based on the work of Davis and Madsen (1941) and Madsen and Davis (1949) who found that normal calves were born to cows receiving 40 mg. per 1000 lb. The National Research Council recommends 60 mg. per 1000 lb. "to provide for normal growth and reproduction and to build up and maintain a moderate storage of vitamin A." The National Research Council recommendation of 300 mg. daily for lactation is based on the work of Kuhlman and Gallup (1941) and that of Hauge et al. (1944). Thus, a daily intake of 300 mg. by the dairy cow is estimated to provide for the production of milk with maximum vitamin A potency and which, according to the National Research Council, should furnish about the equivalent of 6 mg. of carotene per 100 lb. for suckling calves. Morrison's (1948) standards for gestation and lactation are 55 and 90 mg. per 1000 lb. per day, respectively. His recommendations are likewise based on the papers of Kuhlman and Gallup (1941), Davis and Madsen (1941), Madsen and Davis (1949) and the National Research Council (1950).

In line with the National Research Council (1950) recommendations for lactation, Baker (1953) fed Hereford cows 300 mg. of carotene per day during the first three months of lactation. This level of supplementation resulted in apparently normal plasma and liver carotene and vitamin A in the calves of one trial, but blood values indicative of a borderline deficiency in another trial. Also, it resulted in normal blood carotene and vitamin A levels in the cows.

Mohler (1939) reported that when the carotene of blood decreased to 25 mcg. % and blood vitamin A to 16 mcg. % or less, most animals begin to

manifest early symptoms of avitaminosis A. Madsen and Davis (1949) found that reproduction in cows was poor when plasma vitamin A dropped below 18 mcg. % at or near the end of gestation. Payne and Kingman (1947) found that blood carotene levels of 82 mcg. % were sufficient for aged cows, but that heifers need more than 97 mcg. %. A blood level of 117 mcg. % was adequate for heifers. Watkins and Knox (1950) found less carotene than this in the blood of range cows during winter months in New Mexico, but noted no difficulty with reproduction. Similarly, much lower figures are given by Sutton and Soldner (1945), Baker et al. (1954) and Church et al. (1955). Some of the discrepancies noted when using blood data may be due to several factors. Sutton and Soldner (1945), Long et al. (1952) and others have noted marked seasonal variations in blood carotene. Braun (1945) reported that lower blood vitamin A resulted from parturition, abortion, or acute infections, although these changes appeared to be independent of changes in blood carotene. Kuhlman and Gallup (1941, 1944), Van Arsdell et al. (1950), Sutton and associates (1945) and others have reported lower carotene and vitamin A blood levels associated with parturition and beginning lactation.

Only a limited number of reports are available in which the liver storage of vitamin A and carotene have been followed during gestation or lactation by biopsy or slaughter techniques. Data reported by Guilbert and Hart (1934) indicate that lactation results in a more rapid depletion of liver reserves than gestation. Baker et al. (1954) and Church and co-workers (1955) found that liver stores were depleted rapidly during gestation and lactation on low-carotene rations. Carotene supplied at a level of 60 mg. per day (Baker et al., 1954) was not sufficient to prevent depletion of liver reserves during gestation. When supplied at levels of 300 mg. per day (Baker, 1953; Baker et al., 1954) during the first three months of

lactation, a slight increase in liver vitamin A occured in one trial, but further depletion was observed during a second experiment. Jones and associates (1955) reported that carotene fed to dairy cows at levels of 130 and 390 mcg. per kg. was sufficient to maintain liver vitamin A at levels of 12.4 and 18.7 mcg. per gm., respectively. These are very low liver reserves in light of the data reported on beef cows. No information was given on stage of lactation when the liver samples were obtained.

Braun (1945b) found that a correlation between vitamin A liver stores and blood vitamin A existed only when the liver vitamin A fell below "normal" levels. Similarly, Baker et al. (1954), Hjarde et al. (1954) and Jones and co-workers (1955) noted only small differences in the liver concentration of vitamin A of cows given different levels of carotene. However, in dairy calves, Rousseau et al. (1954) reported that when plasma and liver vitamin A were expressed as logarithms, a positive linear relationship existed. It should be noted that the range in which he studied the relationship was rather low for liver stores of vitamin A. Thomas and Moore (1952) likewise reported that on a ration of natural feedstuffs the level of carotene intake was linearly related to liver storage in calves.

The Carotene Requirement of Calves:

Only a few papers are available concerning the carotene requirement of dairy calves, and none on beef calves. Reports by Moore (1939), Boyer et al. (1942), Rousseau et al. (1954b) and Moore and co-workers (1943, 1948) indicate that dairy calves require slightly over 30 mcg. per lb. depending upon the criteria used in evaluating the requirements. Carotene intakes which prevent night blindness may still be low enough to result in increased cerebrospinal fluid pressures (Moore et al., 1948).

Plasma vitamin A and carotene levels indicative of adequate vitamin A

nutrition apparently are lower in the calf than in mature cattle. Boyer et al. (1942) state that a blood level of 10 mcg. % vitamin A was adequate and that levels of 7 to 8 mcg. % were borderline levels. Moore (1939) reported that when plasma carotene fell below approximately 13 mcg. %, nyctalopia and papillary edema followed in Holstein and Ayrshire calves.

Utilization of Carotene from Different Sources:

In most studies on carotene requirements reported, natural feedstuffs such as alfalfa hay or prairie hay have been used as the source of the carotene added to the ration. However, several papers indicate that utilization of dietary carotene varies according to the source used. Investigations by Hoefer and Gallup (1947) with sheep, and King and associates (1940) with cattle, show that carotene from alfalfa is more readily available than crystalline carotene in oil. Eaton et al. (1952), working with Guernsey calves, found that dehydrated hay resulted in higher blood levels of carotene and vitamin A and greater liver stores of vitamin A than field-cured alfalfa. Hansen and co-workers (1954) fed dairy cows artificially dried and chopped alfalfa, dried and pelleted alfalfa and field-cured and baled alfalfa hay and found that carotene utilization as determined by output in milk was best, percentagewise, from the field-cured hay, although the greatest quantities were found in the milk of cows receiving the dried and chopped hay. Gross and Mead (1941) compared blood changes of depleted cows fed various levels of carotene in oil as compared to carotene supplied by fresh alfalfa. There was no marked effect on blood values due to the source of carotene supplied, however the data did not allow direct comparison of the carotene sources. Hauge et al. (1944) found that dried alfalfa hay and carrot oil were of equal value as carotene sources for production of milk vitamin A. Parrish, Aubel and Hughes (1953) compared carotene in oil with

that from alfalfa and from corn. When fed in comparable amounts, the carotene from alfalfa was the most potent source of vitamin A. The vitamin A-active carotenoids of corn were of similar value to those found in alfalfa. Hentges and associates (1952) found that carotene from dehydrated alfalfa meal or pellets restored blood levels of depleted pigs to normal more rapidly than crystalline carotene in oil, sun-cured alfalfa hay or yellow corn. With laying hens, Frey and Wilgus (1949) found that carotene in oil was utilized less efficiently than that in alfalfa. Also, carotene from fresh alfalfa was utilized somewhat more efficiently than that in dehydrated alfalfa. Lecithin has been reported to improve carotene utilization in the rat (Esh and Sutton, 1948) and the source of oil used in a human diet affects the carotene utilization (Chou and Marlatt, 1953).

Structural differences in carotenoids affect its utilization. Kemmerer and Fraps (1943) reported that the purified carotene fraction of alfalfa meal was largely a mixture of all-trans-B-carotene, whereas Bickoff et al. (1949) reported that as much as 60 percent of the carotene from dehydrated alfalfa meal existed in partially cis forms. One cis isomer, neo-B-carotene B has 53 percent of the growth-promoting activity of all-trans-B-carotene for rats (Deuel, 1945). Similarly, alpha carotene has been reported to possess 53 percent of the vitamin A activity of beta carotene for growth of rats (Deuel et al., 1945b) and only 25 percent for liver vitamin A storage by rats (Johnson et al., 1947). No data on the biological value of various carotenoids for the bovine are available.

In summary, experiments with dairy cattle have indicated that carotene needs during gestation are more critical than those reported for beef breeds. However, experiments covering several generations with beef cattle indicate that they require approximately 40 mg. per 1000 lb. of body weight per day for successful reproduction of normal calves. Requirements for

milk production seem to be no higher than this. With beef cows, 300 mg. has been demonstrated to be enough to prevent clinical symptoms of avitaminosis A in suckling calves until three months of age and to be approximately enough to maintain liver reserves in the cows. Dairy cows will produce milk with maximum vitamin A potency when receiving 200 to 300 mg. of carotene daily. Requirements of dairy calves have been shown to be slightly above 30 mcg. per lb. of body weight with some variation among breeds. Some blood studies indicate that plasma vitamin A levels much below 18 mcg. % for any length of time in mature cattle may result in reproductive disturbances, while in the calf, plasma vitamin A lower than 10 mcg. % is considered inadequate. Liver studies have shown that carotene intake or plasma vitamin A is related to liver stores only when liver stores are relatively low, and carotene utilization has been shown to vary according to the source used in supplementing deficient rations.

Carotene Studies with Fattening Steers

Rate of Depletion of Vitamin A Reserves:

Only a limited number of reports are available which provide information on blood or liver concentration in relation to the carotene or vitamin A intake of fattening steers. Early work by Guilbert and Hart (1935) indicated that cattle on a fattening ration deplete liver reserves of vitamin A more rapidly than cattle on a maintenance ration. Jones et al. (1938) reported studies on the time required to produce night blindness in steer calves and yearlings. The range of depletion time varied from 91 to 231 days for yearlings and 101 to 206 days for calves. No other symptoms of avitaminosis A were observed in this trial. From the results of an extensive series of fattening trials, these workers recommended 1.6 mg. per 100

lb. of body weight for optimum feedlot performance. Riggs (1940) observed that range cattle put on carotene-deficient rations became night blind in 46 to 266 days depending on their age, the nature of the ration, and the previous nutritional history. In one trial, steer calves were depleted in an average of 86 days and heifers in 98 days. Schmidt (1941) found that weanling steer calves on a low-carotene ration evidenced typical vitamin A deficiency symptoms after 120 days. Arrested gain, loss of weight, rapid respiration and frequent convulsions were particularly noticable. Jones et al. (1943) reported that feeder calves ranging from 3 to 16 months of age became night blind in 45 to 268 days. Young animals were depleted in less time than older animals. Frey and Jensen (1946) found that a feeding period of 166 days resulted in severe depletion of liver reserves even though there was considerable carotene in the ration, and Madsen and Earle (1947) reported that anasarca and convulsions appeared in steers after 177 days on a low-carotene ration.

Carotene Requirements of Fattening Steers:

Schmidt (1941) reported that one-half pound of recently cut field-cured alfalfa would bring about remission of avitaminosis A in steers. Carotene from alfalfa meal at a level of 1.25 mg. per 100 lb. prevented all deficiency symptoms except infrequent convulsions and night blindness. Jones et al. (1943) found that no liver storage of vitamin A occured in steers given 1.8 mg. per 100 lb. of body weight. Slight storage was evident at 2.5 and 3.0 mg. levels. The authors recommended 2.0 to 2.5 mg. per 100 lb. of body weight for fattening rations.

Frey and Jensen (1946) fed steers on a fattening ration an average of 309 mg. of carotene daily and steers on a maintenance ration 963 mg. of carotene daily. Neither ration was sufficient to maintain initial liver

stores as estimated by slaughter technique, although the steers on the maintenance ration did have more vitamin A in their livers when slaughtered after 166 days on feed. Madsen and Earle (1947) fed steers a concentrate made up chiefly of corn with oat straw as the roughage. An estimated daily carotene intake of 13.6 mg. did not prevent the appearance of symptoms of avitaminosis A after 177 days on feed. Pope et al. (1954) added 20.5 mg. of carotene from a crude alfalfa concentrate to a basal ration of shelled corn, one lb. of alfalfa hay, sorghum silage and cottonseed meal for fattening steer calves. The basal ration was calculated to supply approximately 30 mg. of carotene per head. No consistent differences were observed in average daily gain or efficiency of feed utilization over the 165 day test between steers of the supplemented lot and those on the basal ration.

In summary, feedlot studies have shown that steers fed low-carotene rations are likely to become deficient early enough to cause some trouble in most feedlot operations. The time required to deplete feeder cattle appears to be a function chiefly of age and previous carotene intake, since each factor has some influence on liver vitamin A stores. Some studies show that carotene supplied at a level of 2.0 to 3.0 mg. per 100 lb. of body weight daily are adequate for maximum gains. Others have indicated that fattening steers getting up to 309 mg. of carotene daily were not able to maintain liver reserves, and that steers on a maintenance ration did not maintain liver reserves when receiving more than 900 mg. per day.

PART I. OBSERVATIONS ON PROBLEMS ASSOCIATED WITH A LIVER BIOPSY TECHNIQUE USED IN VITAMIN A STUDIES WITH BEEF CATTLE

The importance of the liver as a depot for vitamin A storage has long been recognized. However, studies concerning the metabolism of carotene and vitamin A with large animals have been hampered by the necessity of slaughtering the animal to obtain liver samples. The development of a liver biopsy technique for cattle by Whitehair et al. (1952) overcame this obstacle. Samples large enough for analysis by conventional methods can be readily obtained without sacrificing the animal. Also, repeated samples may be taken from the same animal to follow the course of depletion or repletion of liver vitamin A stores.

Certain problems in the use of this technique may confront workers in the field such as: (a) the effect of repeated liver biopsies on the tissue near the biopsy site; (b) possible adverse effects of repeated biopsies on the experimental animals, and (c) the validity of this technique in estimating liver vitamin A concentration.

Effect of Liver Biopsies on Cattle:

Liver samples have been obtained successfully from cattle varying in age from newborn calves to mature cows, as has been previously reported by Whitehair et al. (1952). More than 700 operations have been performed on cattle at the Oklahoma Experiment Station with the loss of one cow and three calves, all due to excessive hemorrhage shortly after the operation.

Calves biopsied shortly after birth have been observed nursing their dams in less than an hour after the operation. Steers biopsied in metabolism stalls during carotene balance studies continued to perform in a

satisfactory manner with no apparent ill effects. In a limited number of cases, liver biopsies have been performed at two-week intervals without adverse affects on yearling cattle. Liver samples have been satisfactorily obtained from pregnant cows midway in gestation and again from the same cows immediately after parturition without hindering the normal processes of reproduction and lactation. It is apparent that the trauma caused by liver biopsy using this technique is not sufficiently severe to materially affect normal body processes. Other than a few cases of mild infection at the site of the incision, no detrimental effects have been observed.

Repeated biopsies have been performed on the same animal to study hepatic depletion. Liver samples were taken at monthly intervals for a twelve-month period from two cows and two steers. The animals were then slaughtered and their livers examined for tissue damage (Van Arsdell, 1952). A very limited amount of scar tissue and only a few adhesions were observed. This was not believed sufficient to cause difficulty to the animal, nor to affect the integrity of the liver tissue in the region where the samples were excised. In another study, liver samples were taken periodically from four beef cows over a period of 43 months during a depletion study. In all, 17 samples were taken from each cow. Despite adhesions between the liver and peritoneum and a marked development of superficial scar tissue near the point of incision, making subsequent biopsies more difficult, no apparent ill effects were observed in the cows. Each cow completed two gestation-lactation periods (Church et al., 1955).

Distribution of Vitamin A in the Liver:

Since a biopsy sample is from only a small area of the liver, it seems necessary to determine if such a sample truely reflects liver vitamin A concentration. Guilbert and Hart (1935) reported that from 67 to 93 percent

of the vitamin A body stores of cattle are found in the liver. However, the distribution of vitamin A within the liver of beef cattle has not been extensively studied. Van Arsdell (1952) used four livers in studying this problem. Liver samples of approximately one gram were obtained in duplicate from six locations from the livers of freshly slaughtered cattle. The mean vitamin A values and standard error of the 12 samples from each liver were:

Liver	Vitamin A (mcg./gm. wet tissue)	Standard Error
A	14.3	.72
B	8.2	.53
C	66.3	2.53
D	12.2	1.04

When Bartlett's test of homogeneity of variances was applied to the variances from which these standard errors were calculated, it appeared that there was little chance that the variances were from the same population. Small standard errors were associated with low vitamin A values, and as the mean vitamin A content of the liver increased, the standard error of the mean also increased. The average standard deviation between samples taken in the same location was 2.1 mcg. per gram. Although there was not enough data to show which location in the liver was the most reliable in measuring vitamin A stores, it appeared that the location from which the biopsy samples were taken (dorsal lobe of liver) was as representative as any other area.

A further study reported herein was undertaken to determine the accuracy and precision with which the biopsy samples estimate the vitamin A content of the entire liver. In two trials, a total of 18 cow livers were obtained from a packing plant at time of slaughter and frozen until analyses could be made. Two samples were taken with the biopsy instrument from an

area of the dorsal lobe of the livers which would approximate the actual field of sampling in the intact animal. The remainder of the liver, after the removal of large blood vessels and connective tissue, was finely ground and mixed while still in a frozen state. Two samples of the ground liver tissue were taken at random, and both biopsy sample and ground sample were refrozen until the time of analysis. Two vitamin A determinations were done on each biopsy and each random (ground liver) sample, so that a total of eight determinations were completed on each liver. These data are presented in Table 1.

Biopsy samples 1 and 2 are essentially random samples of liver obtained from within a limited area of the whole liver, and as such may not lead to an accurate estimate of the vitamin A content of the entire liver. Analyses A and B of random samples 1 and 2 of each liver are each essentially a random sample of the whole liver, and A and B, although more closely related than 1 and 2, have no known position relationship such as A and B of the biopsy samples which were in juxtaposition to each other in the liver.

Examination of the data in Table 1 reveals that there is a considerable variation in the vitamin A content of the various samples. The biopsy samples and the random samples had mean vitamin A contents of 572 and 461 mcg. per gm. of dry matter, respectively. The biopsy samples contained 111 mcg. more vitamin A than the random samples, or a percentage difference of 24.

The statistical analysis is presented in Table 2. For each method this table shows that by far the majority of the variance accounted for is due to differences in the vitamin A content of the various livers, a biological phenomenon which would be anticipated.

The error mean square of all liver data would be used to set confidence limits on means of these 18 livers. Using this term, the standard

TABLE 1

The Vitamin A Content of Liver Samples Obtained from the Site of Biopsy and of Random Samples of Ground Liver (mcg./gm. dry matter)

Liver No.	Biopsy Sample*					Random Sample*				
	1		2		Mean	1		2		Mean
	A	B	A	B		A	B	A	B	
1	374	307	317	354	338.0	209	192	158	216	193.8
2	573	703	553	383	553.0	426	351	405	393	393.8
3	869	916	926	881	898.0	791	748	796	814	787.2
4	645	686	842	746	729.7	674	710	542	548	618.5
5	569	653	587	696	626.2	454	423	411	453	435.2
6	678	539	874	738	707.2	424	429	510	595	489.5
7	639	642	666	614	640.2	588	586	521	509	551.0
8	323	283	339	293	309.5	270	198	228	200	224.0
9	608	610	509	658	596.2	357	358	363	365	360.8
10	1119	971	831	861	945.5	687	631	771	815	726.0
11	789	807	831	826	813.2	370	595	373	380	429.5
12	294	295	355	395	334.8	553	595	281	308	434.2
13	495	636	577	617	581.2	530	517	515	445	501.8
14	485	454	442	401	445.5	384	393	517	392	421.5
15	642	537	481	432	523.0	520	474	462	491	486.8
16	374	404	394	324	374.0	413	421	443	408	421.2
17	271	201	364	616	363.0	357	356	365	362	360.0
18	542	428	469	612	512.8	556	421	445	438	465.0
Mean					571.7					461.1

* A and B represent chemical analyses on portions of the larger samples represented by number (1 or 2).

TABLE 2

Statistical Analysis of Liver Data

Source	Analysis of Variance d.f.	MS	F	P
All Liver Data				
Total	143			
Livers	17	211,658	37.4	.0005
Method	1	440,675	80.0	.0005
L x M	17	26,257	4.65	.0005
Error	108	5,650		
Biopsy Samples				
Total	71			
Livers	17	150,715	33.7	.0005
Between Samples 1 & 2 within Livers	18	12,378	2.77	.005
Between A & B within Livers	36	4,474		
Random Samples				
Total	71			
Livers	17	87,199	48.1	.0005
Between Samples 1 & 2 within Livers	18	8,945	4.93	.0005
Between A & B within Livers	36	1,813		

error of the difference (t_{05}) is 111 ± 26 mcg. of vitamin A. To extrapolate from this data, the mean square for interaction is the more appropriate term, giving a standard error of the difference of 111 ± 57 mcg. Thus, for livers with about the same range of vitamin A content, the biopsy samples would be expected to contain from 54 to 168 mcg. more vitamin A than random samples from the same livers. The data from this study indicate that liver tissue from the biopsy area contains more vitamin A than other locations in the liver. Van Arsdell (1952) found no appreciable difference

in the vitamin A content of liver samples obtained from six locations of the liver. However, the livers which he used were much lower in vitamin A content than the livers used in the study reported herein. It may be that as the vitamin A concentration of the liver increases preferential storage occurs in some locations. Also errors in sampling and determination may be magnified at higher vitamin A concentrations.

The error mean squares of the biopsy samples, 4,474, and of random samples, 1,813, show that sub-samples A and B of the ground liver (random samples) are a more precise estimate of liver vitamin A in samples 1 and 2 than sub-samples (A & B) from a biopsy core. This would be expected, particularly if a storage or deposition gradient in vitamin A occurs between different locations in the liver, and the large difference between means of the biopsy and ground samples indicates that this occurs. Likewise, if stratification occurs from dorsal to ventral surface of the liver, the ground samples should lead to a more precise estimate of vitamin A concentration.

The variance of 1 and 2 of the biopsy and random samples is found by subtracting the mean square for A and B within livers from the mean square for 1 and 2 within livers and dividing by two as shown below:

Biopsy Samples	$(12,378 - 4,474)/2 = 3,952$
Random Samples	$(8,945 - 1,813)/2 = 3,566$

This component analysis shows that when two biopsy samples are taken from an area of the dorsal lobe of the liver the precision with which they estimate the vitamin A concentration of that area is almost as good as the precision with which the ground samples estimate the vitamin A in the entire liver.

Most of the liver biopsy work at this station has been done with cattle which were partially depleted of vitamin A. Therefore, the liver samples obtained have, as a rule, contained less vitamin A than the ones involved in this study. Thus, when working with lower concentrations of vitamin A, less variation would be expected. Van Arsdell (1952) found this to be true with the limited amount of data which he reported.

Since only a limited amount of information is available concerning the site of storage of liver vitamin A, extrapolation of the results of the liver study reported herein might lead to large errors in estimating liver concentrations of vitamin A. In order to profitably employ this biopsy technique, more complete data should be available on livers which fall within the range of vitamin A concentration likely to be encountered.

PART II. THE EFFECT OF PLANE OF NUTRITION ON THE DEPLETION OF LIVER VITAMIN A STORES OF BEEF CATTLE DURING GESTATION AND CAROTENE REQUIREMENTS DURING EARLY LACTATION

The carotene or vitamin A dietary requirements of cattle throughout the year are greatly influenced by their ability to store large quantities of vitamin A in the liver and body fat during the grazing season. A survey of the literature indicates that dairy cattle are more demanding in their requirements than beef cattle during gestation, at least this appears to be so in experiments involving relatively short periods of time. This apparent discrepancy between breeds may be due to lower liver reserves in dairy cows since several experiments have pointed out that lactation without supplementation with carotene will rapidly deplete liver vitamin A reserves in beef cattle (Baker et al., 1954; Church et al., 1955).

In previous studies with beef cows at this station, all known essential nutrients other than carotene were supplied. However, vitamin A deficiencies in the field are often believed to be accompanied, or complicated, by malnutrition. The experiments reported herein were designed to study the possible effect of low levels of nutrient intake on the depletion of vitamin A stores of beef cows during gestation and carotene requirements during early lactation.

EXPERIMENT I

Experimental Procedure

Eighteen, bred, two-year-old Hereford cows due to calve in April and

May were selected from the experimental herd in November, 1953, and eight three-year-old Hereford cows were purchased from a neighboring rancher. The two-year-old cows were in their second and third months of pregnancy, whereas, the older cows were farther along in gestation.

The treatments to which these cows were alloted were designed to provide two different levels of nutrition, with low and medium levels of carotene supplementation while nursing calves. The daily allowances of supplemental concentrates and carotene per cow were as follows:

Gestation Phase (no supplemental carotene)

Lots I & II -- 1 lb. cottonseed meal
Lots III & IV -- 2.5 lb. cottonseed meal and 1 lb. ground milo

Lactation Phase

Lot I -- 1.5 lb. cottonseed meal, 2 lb. milo, 2 lb. dried beet pulp and 30 mg. of carotene
Lot II -- Same as Lot I, except for 150 mg. of carotene
Lot III -- 3 lb. cottonseed meal, 4 lb. milo, 2 lb. dried beet pulp and 30 mg. of carotene
Lot IV -- Same as Lot III, except for 150 mg. of carotene

The roughage fed to all lots during the experiment consisted of weathered range grass, cut in early December and found to be devoid of carotene upon chemical analysis. In addition, the cows had access to a mineral mixture composed of equal parts of ground limestone, steamed bone meal and salt. The ration fed to Lots III and IV 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. The ration for Lots I and II, when fed with such a low quality roughage, was deficient in both digestible protein and T.D.N.

Statistically, this experiment was set up essentially as a completely randomized design with a factorial arrangement of the treatments so that

there were all possible combinations of the two levels of feeding and carotene supplementation. At the start of the experiment the cows were randomally assigned to one of the two levels of feeding. At calving, the first cow on the low level of feeding was assigned to Lot I, the next to Lot II, etc. This procedure was followed in allotting all cows to each level of carotene supplementation.

At the beginning of the experiment liver biopsy samples were collected using the technique of Whitehair et al. (1952). Liver samples were also obtained immediately after parturition and after three months of lactation from the cows and at three months of age from the calves. Weights and blood samples were taken at the initiation of the study and at approximately monthly intervals throughout gestation. Weight data, blood and milk samples were collected from the cows, and blood samples and weight data on the calves, at parturition and 2 weeks, 6 weeks and 3 months post partum.

Supplemental carotene was provided during lactation by means of a crude carotene concentrate* from alfalfa which contained approximately 5 mg. of carotene per gm. The concentrate was mixed with cottonseed meal and fed twice weekly.

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 mean liver levels of carotene and vitamin A for cows and calves

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

are presented by lots in Table 3. Plasma carotene and vitamin A data for the cows and calves, and milk vitamin A, are presented in Table 4, with weight data in Table 5. Data for the individual animals are presented in Appendix Tables 12 through 18.

Gestation Phase:

The initial liver vitamin A reserves of the cows in this experiment were extremely variable, ranging from 119 to 587 mcg. per gm. of dry matter. The mean values would seem to be rather high in comparrison to other studies, particularly since pasture grasses were much below average during the summer grazing season.

Examination of Table 3 reveals no apparent effect on depletion of liver vitamin A associated with levels of feeding in this trial. When comparing Lots I and II, the greater depletion of liver vitamin A during gestation which occured in Lot II (Table 3) can be accounted for by one cow whose liver vitamin A dropped from 587 mcg. initially to 54 mcg. at parturition. If this cow were omitted from the data, the magnitude of depletion of liver vitamin A would be essentially the same in Lots I and II, or about 200 mcg. decrease in liver vitamin A stores compared to approximately 236 mcg. for Lots III and IV.

The blood data (Table 4 and Appendix Table 13) show that at the initiation of the study the cows were in an adequate state of vitamin A nutrition. Depletion of blood carotene occurred rapidly whereas vitamin A declined at a slower rate. Plasma carotene and vitamin A in April and at parturition were at levels which have been considered indicative of vitamin A deficiency in mature cattle (Madsen and Davis, 1949), however no clinical symptoms of avitaminosis A were observed at any time. Blood levels

TABLE 3

Mean Carotene and Vitamin A Concentration
of Liver of Cows and Their Calves
(mcg./gm. dry matter)

Item	Lot No.	Treatment*	Initial Sample	Parturition Sample	3 mo. Postpartum
			Cows		
Carotene	I	LL'	16.5±5.2	7.5±6.7	6.8±1.0
	II	LH'	11.0±4.4	7.5±6.7	6.0±1.6
	III	HL'	10.3±2.6	5.8±2.6	4.4±1.3
	IV	HH'	16.8±7.8	6.3±4.9	7.7±1.4
Vitamin A	I	LL'	311.0±105.3	110.5±87.3	63.5±55.5
	II	LH'	312.8±168.7	57.2±37.7	16.5±10.3
	III	HL'	317.4±124.5	88.6±61.9	17.0±13.7
	IV	HH'	303.6±103.3	74.3±44.3	20.8±11.7
			Calves		
Carotene	I				1.8±0.8
	II				1.8±2.0
	III				1.7±1.5
	IV				1.2±0.7
Vitamin A	I				2.1±2.0
	II				3.6±4.5
	III				2.2±1.6
	IV				2.1±0.8

* L - Low Level of Nutrition
L' - 30 mg. of Carotene per Cow per Day
H - Adequate level of Nutrition
H' - 150 mg. of Carotene per Cow per Day

of both carotene and vitamin A in Lots III and IV remained slightly above those of the other two lots during most of the gestation period, but at parturition, blood vitamin A in Lots III and IV was slightly lower than in the other two lots.

The majority of the cows were in rather thin flesh at the beginning of this experiment and their initial weight was below average. The roughage supplied the cows was of very poor quality, containing much trashy and weedy material, hence the cattle did not eat it readily. The cows in Lots I and II, receiving 1 lb. of cottonseed meal daily, lost weight rapidly (Table 5 and Appendix Table 15) and at parturition had lost approximately 128 lb. including the calf, fluids and other tissue loss normally occurring at parturition. Cows in Lots III and IV lost only 54 lb. Thus, the additional 1.5 lb. of cottonseed meal and 1 lb. of milo which they received prevented an average loss of 74 lb. The low intake of Lots I and II was reflected in the lighter birth weight of their calves, 59 and 55 lb., respectively, compared to 67 and 62 lb. for Lots III and IV, respectively. At birth the calves of Lots III and IV appeared to be somewhat stronger.

One prolapsed uterus and three retained placentas occured at calving among the cows of Lots I and II, whereas only one retained placenta occurred in the other two lots. One calf from a cow on the low level of feeding was dead at birth, however it apparently died due to difficult and protracted delivery caused by sutures which had been placed in the vulva to prevent prolapse of the vagina. Also, one calf from a cow on the adequate level died shortly after delivery. This calf was delivered into a small ditch filled with water and suffocation followed. A dairy calf was placed on this cow so that data could be collected during lactation.

TABLE 4

Mean Plasma Carotene and Vitamin A of Cows During Gestation and Lactation and of Their Calves from Birth to Three Months of Age; Mean Vitamin A Content of Colostrum and Milk at Intervals During Lactation (mcg./100 ml.)

Item	Gestation		Parturition	Lactation	
	Nov. 53	Feb. 54		6 weeks	3 mo.
Cows					
Plasma Carotene					
Lot I	132.5±36.2	27.7± 5.3	17.2± 9.2	33.8±16.1	25.5±10.2
II	115.7±24.2	27.5± 8.2	23.0±14.1	72.7±28.8	61.5± 8.6
III	144.4±60.9	24.6± 6.3	24.7±17.2	17.7±11.0	27.8± 9.8
IV	158.7±73.5	32.7±11.2	20.8± 9.7	74.2±57.8	67.3±19.9
Plasma Vitamin A					
Lot I	30.5±3.3	15.6±2.3	16.6±4.8	18.0±2.3	15.2±2.9
II	32.2±4.4	17.9±4.2	17.0±8.1	21.5±5.1	21.6±7.0
III	36.8±6.1	19.3±2.9	13.5±6.5	15.3±4.5	16.5±4.5
IV	35.3±5.2	20.6±2.1	14.3±5.0	19.1±7.9	20.4±2.8
Milk Vitamin A					
Lot I			56.5±61.6	4.0±2.6	4.4±1.8
II			49.3±50.4	4.9±1.6	4.0±0.5
III			69.7±54.6	5.2±4.2	7.4±4.7
IV			27.8±29.5	5.2±3.3	5.5±1.1
Calves					
Plasma Carotene					
Lot I			4.3±5.5	5.2±6.9	14.7± 4.5
II			4.2±2.5	6.5±2.2	12.6± 4.3
III			2.0±3.4	2.0±1.8	11.7± 3.2
IV			2.8±3.6	5.8±5.8	16.9±10.0
Plasma Vitamin A					
Lot I			9.6±5.2	10.1±5.5	8.9±0.5
II			8.7±2.3	7.6±2.1	8.0±1.9
III			7.9±2.8	7.2±1.7	8.0±2.4
IV			6.2±1.4	9.1±2.2	7.6±2.5

Lactation Phase:

Examination of the liver data in Table 3 and Appendix Table 12 reveals no apparent trend due to carotene supplementation or level of feeding. However, to make direct comparisons between liver stores at parturition and 3 months post partum, only those cows which remained in the experiment the full time have been compared (Table 9). Since two calves died in each of Lots I, II and III between one and three months of age, liver data from their dams were not included in this table. This data shows that supplementation with either 30 or 150 mg. of carotene did not prevent further depletion of liver reserves. It should be pointed out, however, that supplementation with 150 mg. reduced the magnitude of depletion as compared to 30 mg. The concentration of liver vitamin A at the end of the trial in Lots I and III, receiving 30 mg. of carotene, was 74 and 96 mcg. less, respectively, than at parturition; likewise, the concentration of liver vitamin A in Lots II and IV was reduced by 42 and 53 mcg., respectively. Or stated another way, Lots II and IV lost only 57 and 55 percent, respectively, as much vitamin A as Lots I and III. When comparing Lot I with III, and Lot II with IV, it will be seen that the low level of feeding resulted in less liver depletion during lactation. The depletion in Lots III and IV represents 113 percent of that in Lots I and II. This greater depletion of liver vitamin A in the cows on the adequate level of feeding may be a reflection of their greater body weight and higher milk production.

Upon examination of the blood data (Table 4 and Appendix Table 14), it will be seen that supplementation with 30 mg. of carotene was sufficient to maintain or increase slightly the plasma vitamin A and carotene.

The 150 mg. level produced a highly significant increase in plasma carotene (P=.01) and a significant increase in plasma vitamin A (P=.05). However, these blood levels were still below those considered normal for beef cows (Long et al., 1952).

Treatment during gestation had no effect on the vitamin A content of colostrum in this experiment. Likewise, there was no demonstrable effect of carotene supplementation on milk vitamin A in milk samples obtained periodically throughout the trial. These data (Table 4 and Appendix Table 13) are comparable to those reported by Baker (1953) who observed no appreciable effect on milk vitamin A even at supplemental levels of 300 mg. of carotene per cow daily.

The rations which cows of Lots I and II received during lactation were sufficient to produce some increase in weight of the cows from parturition to three months post partum (Table 5 and Appendix Table 16), but judging by the weight and appearance of their calves, were not adequate for optimum milk production. These cows were in very poor condition and had not shed their winter hair completely by the end of the experiment in August. Although two cows in Lot I raised good calves, all cows in Lots I and II were in extremely poor condition by the end of the three month period. Cows in Lots III and IV gained more during lactation than the cows in the other two lots, shed off their winter hair, and were in good flesh at the termination of the experiment.

No differences in liver vitamin A or carotene in the calves (Table 3 and Appendix Table 12) were produced by carotene supplementation of their dams, and the liver vitamin A stores observed were indicative of a borderline or deficiency state of vitamin A nutrition. Blood data (Table 4) bears this out. The different levels of carotene supplementation of their

TABLE 5

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

Lot No.	Gestation Nov.	Gestation Feb.	Parturition	Loss to Parturition	Lactation 6 wk.	Lactation 3 mo.	Gain in 3 mo. period
			Cows*				
I	775	752	665	110	668	677	12
II	750	729	603	147	632	648	45
III	770	765	690	80	748	772	82
IV	724	746	696	28	768	758	62
			Calves*				
I			59		89	128	69
II			55		79	109	54
III			67		109	155	88
IV			62		103	152	90

* These means do not include the weights of any cow or her calf where the calf failed to survive for three months after birth. Two calves died in each of Lots I, II and III.

dams likewise resulted in no differences in the blood vitamin A or carotene of the calves. During the latter part of the experiment, the calves were large enough to eat when the cows were fed, and the calves did obtain some of the supplemental carotene intended for their dams. Therefore, blood data on the calves may not be an accurate reflection of their carotene or vitamin A intake from milk alone. As such, blood levels are undoubtedly higher than they would otherwise be.

Weight of the calves (Table 5 and Appendix Table 18) reveals a difference between the lots whose dams were on different levels of feeding, but no difference between the two levels of carotene intake. This would

be expected from the milk vitamin A data which apparently was not affected by differences in carotene intake.

Two calves died in each of Lots I, II and III. The cause of death in Lots I and II was believed to be a combination of avitaminosis A, secondary infections and malnutrition. That occurring in Lot III was believed to be a result of avitaminosis A and secondary respiratory infections. Diarrhea was a problem to some extent in all lots, although more so in Lots I, II and III. It was kept partially under control during the latter part of the experiment by drenching with sulfathiazole and by feeding Aureomycin (as Aurofac). The general condition of the calves in Lots I and II was good until about one month of age. With two exceptions, from that age until the end of the experiment, their hair coat became rough and the calves appeared undernourished; diarrhea was frequently noted. Several calves in Lots I and II exhibited exopthalmia and night blindness toward the end of the experimental period. However, none of the calves became blind and no incoordination or convulsions were observed.

Although the surviving calves in Lot III grew well, and the heaviest calf in the experiment came from this lot, they were much less uniform and appeared less thrifty than calves of Lot IV. Two calves in Lot IV had persistent cases of diarrhea, however, and did not gain well; indicating that, under the conditions of this experiment, 150 mg. of carotene was not adequate to maintain the calves in an optimum state of vitamin A nutrition until three months of age.

EXPERIMENT II

Experimental Procedure

Twenty-four, bred, two-year-old Hereford cows due to calve in April and May were selected from the experimental herd in November, 1954. These cows were in their second and third months of pregnancy.

The basal rations and treatment for these cows were essentially the same as described in detail in Experiment I, except that Lots I and III received 27 mg. of carotene per head and Lots II and IV received 126 mg. Weight data and liver and blood samples were collected as in Experiment I, except that the terminal samples were taken at 12 weeks post partum. Milk samples were obtained at parturition and at 12 weeks.

The supplemental carotene fed during lactation was a carrot concentrate in soybean oil* which contained approximately 5.5 mg. per gm. It was given twice weekly by capsule to Lots I and III and by dose syringe to Lots II and IV.

Analyses were made for vitamin A and carotene using the same procedures as previously cited.

Results and Discussion

The mean liver levels of carotene and vitamin A by lots for cows and calves are presented in Table 6. Plasma carotene and vitamin A data for the cows and calves and milk vitamin A is presented in Table 7, and weight data in Table 8. Data for the individual animals are presented

* The carotene concentrate was generously supplied by Nutrition Research Associates, South Whitley, Indiana.

TABLE 6

Mean Carotene and Vitamin A Concentration of Livers of Cows and Their Calves (mcg./gm. dry matter)

Item	Lot No.	Treatment*	Initial Sample	Parturition Sample	12 Wk. Post Partum
			Cows		
Carotene	I	LL'	23.0± 3.8	8.8± 1.2	9.7±7.2
	II	LH'	29.0± 7.9	10.2± 4.3	18.0±9.7
	III	HL'	29.3±11.3	8.0± 3.7	9.5±4.2
	IV	HH'	24.3± 7.2	12.8±11.9	17.2±6.3
Vitamin A	I	LL'	396.0±172.0	169.8±71.5	106.0± 64.3
	II	LH'	472.0±223.7	173.8±94.3	153.3±146.3
	III	HL'	462.7±201.4	116.8±67.7	69.5± 80.8
	IV	HH'	409.5±141.8	100.7±72.9	81.0± 56.3
			Calves		
Carotene	I				1.1±1.1
	II				0.8±1.0
	III				1.3±0.8
	IV				1.7±1.2
Vitamin A	I				1.5±1.2
	II				1.6±1.8
	III				1.4±1.1
	IV				3.4±3.5

* L - Low level of nutrition; L' - 27 mg. of carotene per cow per day; H - adequate level of nutrition; H' - 126 mg. of carotene per cow per day.

in Tables 16 through 22, appendix.

Gestation Phase:

The initial liver vitamin A reserves of the cows in this experiment were even more variable than those in Experiment I, ranging from 168 to 804 mcg./gm. of dry matter, as reflected in the large standard errors

(Table 6). The summer of 1954 was very dry and pasture conditions were considered below average, however this was not reflected in the liver vitamin A stores of these cattle. Examination of data in Table 9 reveals that the liver vitamin A of cows on the low level of feeding (Lots I and II) was depleted an average of 262 mcg., while the cows on the adequate level of feeding lost an average of 327 mcg. If expressed as percentage loss, Lots I and II were depleted of 57 and 63 per cent, respectively, of their initial liver vitamin A and both Lots III and IV were depleted of 75 per cent of initial liver stores. Even though the loss during gestation was large, liver reserves remained at levels not considered indicative of avitaminosis A.

The blood data (Table 7 and Appendix Table 20) show that the cows were in a state of adequate vitamin A nutrition at the start of the experiment, but that blood carotene dropped rapidly while vitamin A declined at a slower rate. The increase in plasma carotene (Appendix Table 20) noted in April and at parturition was due to the consumption of a small amount of new grass growing in the traps in which the cattle were kept. Also, three cows in Lot IV got out of the trap for several days and ate sufficient green feed to cause a marked increase in plasma carotene and an appreciable increase in vitamin A.

The cows in this experiment were in thin condition at the beginning of the study, as in Experiment I. The roughage fed was of even lower quality than that used in the first experiment. Weight loss was so rapid that one pound of milo was added to both levels of feeding for about one month during mid-winter to prevent excessive loss of weight. The cows in Lots I and II, receiving the low level of feeding, lost an average of 118 lb. to parturition, and those in Lots III and IV lost an average of 54 lb.

TABLE 7

Mean Plasma Carotene and Vitamin A of Cows During Gestation and Lactation and of Their Calves from Birth to Three Months of Age; Mean Vitamin A Content of Colostrum and Milk at Intervals During Lactation (mcg./100 ml.)

Item	Gestation		Parturition	Lactation	
	Nov. 54	Feb. 55		6 Weeks	12 Weeks
Cows					
Plasma Carotene					
Lot I	362.0±127.7	41.5± 8.5	66.5± 17.8	75.8±19.9	73.5±12.0
II	326.0± 59.0	31.8±16.2	56.8± 33.2	185.5±16.4	193.0±49.5
III	390.3±110.3	31.8± 2.9	57.8± 18.9	91.8±22.3	93.7±21.4
IV	380.0± 68.5	30.3± 4.7	154.0±187.1	247.2±76.3	267.0±62.3
Plasma Vitamin A					
Lot I	36.9±3.6	21.6±6.2	15.4±2.7	21.9±4.2	19.6±4.1
II	35.5±2.2	22.0±1.7	13.0±1.1	22.1±3.6	25.7±4.4
III	27.7±6.5	23.3±3.3	14.8±3.5	22.8±4.6	19.3±4.9
IV	36.4±5.7	22.7±2.6	16.3±4.3	27.3±2.8	24.2±6.9
Milk Vitamin A					
Lot I			156.8± 78.7		3.6±2.5
II			81.2± 5.2		2.0±1.6
III			136.6±130.8		1.0±0.7
IV			29.9± 17.7		1.3±0.7
Calves					
Plasma Carotene					
Lot I			0.0	9.8±1.3	7.9±2.2
II			0.0	11.4±3.5	6.4±3.6
III			2.7±2.7	11.3±1.9	7.5±2.6
IV			1.5±2.4	15.3±2.6	8.0±4.9
Plasma Vitamin A					
Lot I			6.5±3.1	10.2±2.5	2.6±1.4
II			7.4±0.9	9.7±2.9	2.2±2.1
III			6.4±0.9	8.5±3.5	2.9±1.2
IV			8.1±1.5	10.6±2.4	4.0±2.1

(Table 8). Thus the additional 1.5 lb. of cottonseed meal and 1 lb. of milo received by Lots III and IV prevented a loss of 64 lb. as compared to 74 lb. in Experiment I. The low feed intake of Lots I and II was reflected in the lighter birth weight of their calves, 55 and 56 lb., respectively, compared to 63 and 66 lb. for Lots III and IV, respectively. As in the first year, the calves from Lots III and IV appeared to be somewhat stronger at birth. All calves were born alive in this experiment.

At calving, two retained placentas occurred among the cows on each level of feeding.

Lactation Phase:

Examination of the liver carotene and vitamin A data (Table 6) reveals that supplementation with 127 mg. of carotene (Lots II and IV) reduced the magnitude of depletion considerably when compared with those lots receiving 27 mg. (Lots I and III). Table 9 shows that the liver vitamin A concentration in Lots I and III was reduced by 64 and 46 mcg., respectively, while Lots II and IV, receiving 127 mg. of carotene, lost 20 mcg./gm., each. Lot II lost only 31 per cent as much liver vitamin A as Lot I, and Lot IV lost 44 per cent as much as Lot III. When comparing Lot I with III, and II with IV, the data reveal that the low level of feeding resulted in a lower percentage loss during lactation. However, the magnitude of loss in Lot I was greater than that in Lot III, but was the same in Lots II and IV. One cow in Lot III had a higher concentration of liver vitamin A at 12 weeks than at parturition. If this cow were omitted, the loss in Lots I and III would be about the same.

The greater absolute loss in Lot I might be expected, since research

TABLE 8

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

Lot No.	Gestation		Parturition	Loss to Parturition	Lactation		Gain during Lactation
	Nov.	Feb.			6 Wk.	12 Wk.	
				Cows			
I	717	651	598	119	632	639	41
II	752	677	635	117	642	658	23
III	740	785	692	48	752	767	75
IV	767	790	708	60	753	763	55
				Calves			
I			55		88	126	70
II			56		91	132	76
III			63		104	152	89
IV			66		117	167	101

has pointed out that the rate of liver vitamin A depletion decreases as liver reserves decrease. However, this is difficult to interpret in view of the results obtained in Experiment I in which the absolute loss was greater in those lots (III and IV) which received the adequate level of feeding. In this first experiment, it was postulated that the greater body weight and apparently higher milk production in Lots III and IV were responsible for the higher loss of liver vitamin A reserves. It will be seen (Table 9) that the liver vitamin A at parturition was more nearly comparable between Lots I and II and Lots III and IV in 1955 than in 1954. The higher liver reserves in Lots I and III of 1954 would be expected to result in a greater absolute loss than would occur with a comparable ration for Lots II and IV.

TABLE 9

Mean Liver Vitamin A at Five Months Prepartum, Parturition
and Three Months Post Partum
(mcg./gm. of dry matter)

Year	1954				1955			
Level of Feeding	Low		Adequate		Low		Adequate	
Lot Number	I*	II*	III*	IV	I	II	III	IV
Carotene in Lactation mg./cow/day	30	150	30	150	27	126	27	126
mg./100 lb./day	4.5	24.0	4.1	20.8	4.4	19.5	3.7	17.2
Liver Vitamin A								
5 mo. prepartum	339	361	356	304	396	472	462	409
Parturition	138	58	113	74	170	173	116	101
3 mo. post partum	64	16	17	21	106	153	70	81
Loss to parturition	201	303	243	230	226	299	346	308
% of 5 mo. sample	59	84	68	76	57	63	75	75
Loss in Lactation	74	42	96	53	64	20	46	20
% of parturition sample	54	72	85	72	38	12	40	20

* These means do not include the cows whose calves failed to survive for the three month period of lactation.

Supplementation with 27 mg. of carotene per head daily was sufficient to increase the plasma vitamin A slightly at both levels of feeding (Table 7 and Appendix Table 21), and supplementation with 126 mg. produced a significant increase (P=.05) in Lots II and IV when compared with Lots I and III. The lower level of carotene was sufficient to cause some increase in plasma carotene in both lots. Lots II and IV cannot be directly compared, since in Lot IV cows blood carotene was much higher at the beginning of supplementation. Among the individual cows with comparable levels of plasma carotene at parturition, supplementation with 126 mg. in Lot IV produced a greater increase in plasma carotene than in Lot II, and the same situation existed when comparing Lots I and III, although to a lesser extent.

Treatment during gestation had no demonstrable effect on the vitamin A content of colostrum, although the mean for Lots I and II was 119 mcg. % compared to 83 mcg. % for Lots III and IV. Carotene supplementation had no apparent effect on the 12 week sample (Table 7). Milk production at 12 weeks (Table 23) was estimated by obtaining a 12-hour sample of milk. Lots III and IV produced more milk than I and II, but the estimated production of milk vitamin A per day was lower than for Lots I and II. This may be a reflection of the higher liver stores in these two lots.

The rations which Lots I and II received during lactation was sufficient to produce some increase in weight from parturition to 12 weeks post partum (Table 8), but judging by the weight and appearance of the calves, they were not optimum rations for milk production. These cows were in very thin condition and did not shed off completely. The cows of Lots III and IV were in much better flesh and their general condition and

appetite were much better.

The different levels of carotene supplementation produced no significant differences in liver vitamin A among the calves (Table 6). The liver stores of the calves were of the same magnitude as in the previous year. Likewise, there were no differences in the blood carotene or vitamin A in the calves due to level of feeding or carotene supplementation. The carotene and vitamin A blood levels at termination in Experiment II were lower than those of Experiment I, but it should be pointed out that the calves in Experiment II did not have access to carotene in the cows' feed as did the calves in the previous year. The blood levels at six weeks are comparable to those of the previous year, but those at 12 weeks were indicative of avitaminosis A, and some scours and exopthalmia were observed in all lots. Persistent cases of diarrhea were more of a problem in Lots III and I, but even in Lot IV there were two calves that had diarrhea for most of the experimental period. Diarrhea was kept under much better control than in the previous year by including about 30 mg. of Aureomycin (as Aurofac) per pound of creep feed supplied to the calves. Total creep feed consumption for Lots I, II, III and IV was 630, 613, 497 and 525 lb., respectively. The calves of Lots I and II began eating earlier than those of the other two lots, and by the end of the experiment they were consuming more than five pounds of concentrate per calf per day. The calves in each lot were more uniform than those of the previous year. The average gain in Lots I and III was about the same as in 1954, but Lots II and IV gained 22 and 11 lb. more, respectively, in 1955 and appeared to be healthier and more thrifty calves.

The data from these two years may not be directly comparable due to several variables. For one thing, the difference in liver reserves at

parturition would be expected to have some effect on blood carotene and particularly on blood vitamin A when rations are fed which are not adequate to maintain liver reserves. Since it has been shown that feeding a low carotene ration results in a decreasing rate of depletion of liver reserves (Frey and Jensen, 1946, 1947; Baker, 1953 and Church et al., 1955), the cows in Experiment II would be expected to lose more liver vitamin A than cows in Experiment I.

A second variable was the method of administration of the carotene supplement. During the first trial the carotene was mixed with cottonseed meal, while in the second it was given by capsule or syringe. The second method resulted in less depletion during lactation with a lower carotene intake. This is somewhat comparable to data reported by Baker (1953) in that cows given carotene by capsule showed a slight increase in liver vitamin A, whereas when the carotene was mixed with cottonseed meal it did not prevent further depletion. Also, in his data there was quite a difference in liver reserves at parturition favoring those cows which later received the carotene in cottonseed meal. The differences may have been due to the variation in liver vitamin A and not to method of administration. Although individual dosage with carotene was more time consuming and difficult, it is to be recommended since it assures a more uniform intake and helps to reduce the variation within lots.

A third factor which differed between these two experiments is that the sources of carotene were different. A crude alfalfa concentrate was used the first year, while a carrot concentrate in soybean oil was used the second year. Several references previously cited show that the utilization of carotene from different sources varies. It would seem that the source of carotene and its method of administration are factors that

should be taken into consideration in further research of this nature.

The National Research Council recommends that lactating beef cows be given an allowance of 300 mg. of carotene daily for a 1000 lb. cow, or 30 mg. per 100 lb. The carotene supplements in these two experiments (Table 9) were given at levels varying from 3.7 mg. to 24.0 mg. per 100 lb. of body weight. The body weight used in estimating these figures was an average of the parturition and three months post partum weight. In light of the data reported by Baker (1953) and data from Experiment I, 30 mg. per 100 lb. would appear to be necessary to maintain liver vitamin A stores during lactation. Experiment II indicates that this level of supplementation might be higher than necessary to maintain liver vitamin A as several individual cows were able to maintain or increase liver reserves when receiving 126 mg. of carotene daily.

In these experiments, as well as those reported by Baker (1953), there was little correlation between carotene intake and milk vitamin A, pointing out the inefficiency of mammary transfer of plasma vitamin A. The work of Hauge et al. (1944) verifies this. He points out that a carotene intake of 200 mg. per day in dairy cows would result in milk vitamin A levels which were approximately the same as when 300 mg. were fed.

Boyer et al. (1945) stated that blood vitamin A was indicated as a more delicate measure of the vitamin A nutrition of the calf than either growth or blood carotene. This is in general agreement with the results reported herein, particularly when considering the milk data. Wise et al. (1948) reported that consumption of colostrum produced a "striking" increase in blood carotene and vitamin A, but that calves were six weeks old before hay consumption was sufficient to increase blood carotene and

vitamin A even though the calves were fed milk from a herd pastured on green grass. Experiments I and II and those reported by Baker (1953) also agree with Wise et al. (1948) who found that calves which received colostrum and milk from cows getting roughage high in carotene had blood values at four and six weeks of age which were in a state of submarginal deficiency, although no clinical malnutrition was observed. Although calves in a borderline state of vitamin A nutrition may not show the typical symptoms of avitaminosis A, Ritzman and associates (1945) reported that calves on a deficient ration ate more feed but made 50 per cent less gain than those receiving adequate vitamin A. Protein utilization was decreased and digestion, absorption and metabolism of energy were depressed also. These metabolic effects may account for some of the differences observed in calves of the various lots in Experiments I and II.

In the light of the results reported by Wise et al. (1948) and Baker (1953), and Experiments I and II reported herein, it would appear that supplementation with carotene in order to supply vitamin A through the milk to the beef calf is a very inefficient practice. This would be especially true after the calf is old enough to eat roughage in quantity. It would appear that after the calf is six weeks of age, it might be much more economical to supplement the calf directly with carotene or vitamin A when green feed or good quality hays are not otherwise available.

Data from these two experiments indicate that carotene supplementation during the latter part of gestation is not necessary for the production of normal beef calves when the cows have had access to green pasture the previous summer. Furthermore, the data indicate that supplementation during lactation is much more critical for the health of the

calf. It would appear that somewhat less than 300 mg. of carotene would suffice to maintain calves in an adequate state of vitamin A nutrition, at least until the calf is old enough to obtain its carotene or vitamin A supply from some source other than milk.

A submarginal level of feeding during gestation and lactation resulted in less depletion of liver vitamin A and smaller less thrifty calves from these cows, although it had no demonstrable effect on blood carotene or vitamin A levels in the calves.

PART III. ALFALFA HAY AND DEHYDRATED ALFALFA MEAL AS DIETARY SOURCES OF CAROTENE FOR FATTENING STEERS

Alfalfa hay and dehydrated alfalfa meal have been used extensively in steer fattening rations as roughages and also to provide protein and minerals. These two products have also been used as a source of carotene. As a matter of fact, many carotene studies with cattle have used alfalfa as the sole source of carotene. With these facts in mind, the research reported herein was designed to determine the amount of alfalfa hay or dehydrated alfalfa meal necessary to provide adequate carotene for steers when feeding a basal ration likely to be deficient in carotene.

Experimental Procedure

A total of 170 good-to-choice, weanling, Hereford steer calves were used in the feeding trials reported herein. The calves were allotted into uniform groups of ten head each on the basis of source, weight and grade. The rations to be fed were then assigned to the lots at random. All lots received sorghum silage throughout the feeding period which lasted about 165 days. In the first year, Experiment I, ground corn was fed to Lot I, whereas Lots V and VI received rolled milo. In Experiments II and III, all lots were fed milo as the chief concentrate. In addition to corn or milo and silage, the daily ration per head for each lot was as follows:

Experiment I (1953)

Lot I - 1.5 lb. cottonseed meal and 1.0 lb. alfalfa hay
Lot V - 1.85 lb. cottonseed meal
Lot VI - 1.5 lb. cottonseed meal and 1.0 lb. alfalfa hay

Experiment II (1954)

Lot I - 1.8 lb. cottonseed meal
Lot II - 1.35 lb. cottonseed meal and 1.2 lb. alfalfa hay
Lot III - 1.35 lb. cottonseed meal and 0.8 lb. dehydrated alfalfa pellets
Lot IV - 0.9 lb. cottonseed meal and 2.4 lb. alfalfa hay
Lot V - 0.9 lb. cottonseed meal and 1.6 lb. dehydrated alfalfa pellets
Lot VI - 3.2 lb. dehydrated pellets

Experiment III (1955)

Lots I through VI received essentially the same treatments as followed in 1954.
Lot VII - 1.6 lb. cottonseed meal plus 15 mg. of supplementary carotene
Lot VIII - 1.6 lb. cottonseed meal, 15 mg. of supplementary carotene and the ash of 1.0 lb. of alfalfa hay

In Lots II and IV, alfalfa hay replaced one-fourth and one-half of the cottonseed meal on a protein-equal basis. Similar substitutions were made for Lots III and V, while in Lot VI, dehydrated alfalfa meal replaced all of the cottonseed meal. The treatments applied to Lots VII and VIII in 1955 were designed to determine if the effect from alfalfa was primarily due to its carotene content or due to a combination of carotene and ash.

Blood samples were taken at the end of Experiment I (1953). During the two following experiments, samples were taken at the beginning of the experiment, midway through the feeding period and at its termination. Liver samples were obtained when the steers were slaughtered, which was a week to ten days following the last blood sample. Blood plasma was analyzed for carotene and vitamin A according to the method of Kimble (1939) and liver by the method of Gallup and Hoefer (1946). Further detailed information concerning this experiment is given by Bennett (1955).

Results and Discussion

The blood and liver data, along with the average daily gains by lots, are summarized in Table 11. Data from individual steers are presented in Appendix Tables 26, 27 and 28. Table 10 gives the estimated daily carotene intake and Appendix Table 29 gives the average carotene content of the carotene-containing ration constituents.

Experiment I - 1953:

The blood data from the first experiment (Table 11) indicate that a ration composed of milo, sorghum silage and cottonseed meal did not maintain the steers in an adequate state of vitamin A nutrition, and that the steers did not gain as well as those in the other lots. Although there was no statistical difference in average daily gain between any of the three lots, there was certainly a strong trend favoring Lots I and VI.

Toward the end of the trial, steers in Lot V began to show definite clinical symptoms of avitaminosis A. One steer became completely blind and several steers developed anasarca. Likewise, convulsions were observed in several steers. Feed consumption for the entire lot declined, and consequently their rate of gain was less than in the other two lots. Mean blood vitamin A values of 7.7 mcg. % were certainly indicative of a vitamin A deficiency (Moore, 1939)

The addition of one pound of alfalfa hay to the basal ration of cottonseed meal, milo and sorghum silage was capable of supporting growth and fattening at a rate comparable to the lot fed corn and alfalfa (Lot I). Although steers in Lot I had higher blood carotene and vitamin A levels at the end of the trial, apparently the one pound of alfalfa supplied to

TABLE 10

The Source of Dietary Carotene, Estimated Daily Carotene Intake and Average Daily Gain of Steers

Lot No.	Source of Carotene* Feed	Daily Ration (lb.)	Estimated Daily Carotene Intake mg./head	mg./100 lb. Initial	mg./100 lb. Final	Average Daily Gain (lb.)
			1953			
I	Alfalfa Hay & Corn	1.0	32.2	6.81	3.82	2.24
V	None		3.78	0.80	0.47	2.03
VI	Alfalfa Hay	1.0	20.2	4.26	2.40	2.26
			1954			
I	None		12.1	2.35	1.46	1.88
II	Alfalfa Hay	1.2	28.6	5.56	3.42	1.95
III	Dehy. Alf. Pellets	0.8	34.8	6.82	4.09	2.05
IV	Alfalfa Hay	2.4	42.9	8.33	4.97	2.10
V	Dehy. Alf. Pellets	1.6	57.8	11.20	6.65	2.13
VI	Dehy. Alf. Pellets	3.2	95.6	18.64	11.05	2.12
			1955			
I	None		29.1	6.24	3.47	2.29
II	Alfalfa Hay	0.9	40.8	8.55	4.74	2.35
III	Dehy. Alf. Pellets	0.9	40.9	8.78	4.73	2.34
IV	Alfalfa Hay	1.8	54.2	11.63	6.58	2.25
V	Dehy. Alf. Pellets	1.67	46.2	9.85	5.51	2.26
VI	Dehy. Alf. Pellets	3.5	68.0	14.56	8.15	2.25
VII	Carotene Concentrate		44.1	9.54	5.35	2.22
VIII	Carotene Concentrate		44.1	9.44	5.26	2.28

* In addition, all lots received sorghum silage. No carotene analyses were available on the corn fed to Lot I, 1953, therefore Morrison's (1948) analysis for no. 2 corn was used to estimate the carotene intake.

Lot VI provided sufficient carotene for maximum growth, although blood vitamin A levels of 15.1 mcg. % are probably not much more than borderline levels.

Experiment II - 1954:

The performance of the steers in the basal lot (Lot I) in this trial was similar to that of the steers receiving the same ration in the previous year. Blood data (Table 11) indicate that blood carotene and vitamin A dropped rapidly and at the end of the trial the steers were showing definite clinical symptoms of avitaminosis A. In addition to a blood vitamin A level of 13.5 mcg. %, other symptoms such as diarrhea, night blindness, anasarca, and convulsions were noted at the termination of the experiment. Liver vitamin A, likewise, was very low, although neither blood or liver vitamin A levels were as low as those of Lot V of the previous year. An analysis of variance revealed a significant difference between gains of the different lots (P=.01), and orthogonal comparisons revealed that most of this difference was accounted for in the comparison of the basal group (Lot I) with all other lots receiving alfalfa (Bennett, 1955).

Experiment III - 1955:

In this experiment, the addition of alfalfa hay or dehydrated alfalfa meal had no apparent effect on the daily gain when added to the basal ration. The silage used in this trial contained more carotene than in 1954 (Appendix Table 29), and the estimated carotene intake from silage was about 29 mg. per steer per day. Blood levels of carotene and vitamin A in Lot I were slightly lower than those of any of the lots receiving alfalfa or dehydrated alfalfa meal, but were at levels not indicative of a vitamin A deficiency. The only evidence of a deficiency was after slaughter, when mild edema was noted in five carcasses from Lot I.

TABLE 11

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

Lot No.	Blood (mcg. %) October Car.	Vit. A	January Car.	Vit. A	April Car.	Vit. A	Liver (mcg./gm.dry) Car.	Vit. A	Average Daily Gain (lb.)
					1953				
I					81	20.5	4.9	3.3	2.24
V					10	7.7	1.6	0.9	2.03
VI					40	15.1	3.0	2.2	2.26
					1954				
I	103		33	15.4	22	13.5	0.3	1.7	1.88
II	98		55	20.1	51	23.2	13.8	3.3	1.95
III	90		67	19.8	49	23.3	7.8	3.8	2.05
IV	101		65	21.9	77	27.4	7.9	8.2	2.10
V	124		79	21.4	94	29.4	5.6	6.0	2.13
VI	98		128	20.9	145	33.1	9.5	16.4	2.12
					1955				
I	132	31.2	48	19.7	60	18.5	4.2	2.3	2.29
II	120	30.9	72	28.4	90	25.9	4.7	3.6	2.35
III	122	29.6	64	25.6	76	22.1	6.1	3.9	2.34
IV	105	28.7	63	20.4	80	26.9	6.2	3.9	2.25
V	104	28.7	72	17.0	86	21.2	5.1	7.3	2.26
VI	141	34.1	125	30.2	124	25.6	7.6	4.1	2.25
VII	109	31.9	50	18.3	67	18.3	4.0	2.0	2.22
VIII			58	19.1	76	19.6	4.5	2.4	2.28

In Lots VII and VIII which received 15 mg. of supplementary carotene, there was no apparent beneficial effect due to this supplementation. Lot VIII also received the ash of 1.0 lb. of alfalfa. Blood data (Table 11) indicates that the ash slightly increased the utilization of the carotene and resulted in slightly greater gains.

In comparing the data from all experiments, Table 11 shows that blood

carotene and vitamin A were depleted to rather low levels in those lots having a reduced rate of gain. There is not enough data to show with any degree of accuracy what the minimum level of blood vitamin A can be and still have satisfactory gains, but the data indicate that blood carotene levels should be more than 22 mcg. %. In 1953, Lot VI, with terminal plasma carotene levels at 40 mcg. %, made satisfactory gains. The data further indicate that blood vitamin A should be higher than 13.5 mcg. %. Data from the first year indicate that a blood level of 15 mcg. % might be sufficient to support growth, but in the last year (1955) there was some evidence at time of slaughter of vitamin A deficiency in Lot I steers whose blood vitamin A averaged 18.5 mcg. % about ten days before slaughter. This is in general agreement with the work of Madsen and Davis (1948) with mature cattle in that blood vitamin A levels at or below 18 mcg. % are indicative of deficiency. Likewise several reports on dairy calves cited previously indicated that blood levels of 13.5 to 15.0 mcg. % were necessary to prevent symptoms of avitaminosis A.

Further examination of Table 11, particularly the last experiment, shows that none of the lots received enough carotene to maintain their initial blood carotene or vitamin A levels. The blood data show that one pound of alfalfa hay was capable of increasing the blood carotene about 30 mcg. % and the vitamin A 7 to 10 mcg. % over the basal ration. Comparing blood levels with sources of carotene (Tables 10 and 11), alfalfa hay appeared to be a slightly better source for the maintenance of blood carotene and vitamin A than did the dehydrated product. This information agrees with several papers cited previously.

The daily carotene intake (Table 10) was estimated by using the analyses given in Appendix Table 29. In Table 10 the daily intake is expressed

as mg. per head or as mg. per 100 lb. of body weight. The latter method is preferable since vitamin A or carotene is required in proportion to body size. In Table 10 the carotene intake is expressed as mg. per 100 lb. on the basis of both initial and final weight. However, since the carotene intake is estimated by using the average carotene content of the roughages, the figures for intake per 100 lb. of initial weight are undoubtedly too low, and those based on final weight are probably too high. At any rate, they offer a means of comparing lots which received different amounts of carotene and which grew at different rates; also it helps to reduce yearly differences when making comparisons. With this information in mind, examination of Table 10 shows that the carotene intake at the beginning of the trials ranged from .8 to 18.6 mg. per 100 lb. and at the end of the trials from .47 to 11.05 mg. per 100 lb. Although the carotene intake cannot be estimated with great accuracy, the data indicate that carotene fed at a level of 3.5 mg. per 100 lb. was more than adequate, and that possibly a level as low as 2.4 mg. per 100 lb. would be satisfactory. This lower level is in line with the recommendations of Jones et al. (1943). However, these three experiments were of relatively short duration (165 days) compared to feeding periods commonly used in the corn belt, and another 30 to 60 days might have resulted in deficiencies which would not be a problem in these shorter feeding experiments.

Liver vitamin A storage was negligible in all lots in each trial. Liver vitamin A did appear to be slightly correlated with estimated carotene intake, but variation was so great that significant differences did not exist. No information is available concerning the initial liver stores in these experiments, but Jones and associates (1943) found that

slight storage occurred when steers were fed carotene at levels of 2.5 and 3.0 mg. per 100 lb. However, Frey and Jensen (1946) reported that carotene fed at levels as high as 963 mg. per day did not prevent depletion of liver reserves. Data from the experiments reported herein would indicate that a carotene intake of 3.0 mg. per 100 lb. would not be adequate for storage of liver vitamin A, but that certainly much less than 963 mg. would result in liver storage.

In summary, data from these three experiments indicate that blood carotene and vitamin A levels below 40 mcg. % and 15 mcg. %, respectively, are indicative of avitaminosis A in feedlot steers and are apt to be accompanied by a reduced rate of gain and other clinical symptoms of avitaminosis A. The data further indicate that a carotene intake of 2.4 to 3.5 mg. per 100 lb. of body weight is necessary to support satisfactory gains in fattening steers. No apparent liver storage occurred on carotene intakes as high as 96 mg. per day. In these trials which covered about 165 days, approximately one pound of alfalfa hay or the equivalent amount of dehydrated alfalfa meal appeared to be sufficient to maintain steer calves in an adequate state of vitamin A nutrition when fed with a basal ration likely to be deficient in carotene. Further, alfalfa hay was indicated as a slightly better source of carotene than dehydrated alfalfa meal for steers in these experiments.

SUMMARY

Studies were conducted to determine (1) the accuracy and precision of a liver biopsy technique as a means of estimating the vitamin A concentration of the entire liver; (2) the effect of a sub-maintenance plane of nutrition on depletion of vitamin A reserves during gestation and on the carotene requirements of beef cows during early lactation, and (3) the approximate amount of alfalfa hay or dehydrated alfalfa meal required to support satisfactory gains in fattening steer calves and maintain them in a state of adequate vitamin A nutrition.

A statistical analysis of the liver data showed that, within the area of the dorsal lobe normally sampled, the precision with which biopsy samles estimate the vitamin A concentration in that area is almost as great as the precision with which ground samples estimate the vitamin A in the entire liver. Biopsy samples contained 24 per cent more vitamin A, indicating a deposition gradient within the liver.

A sub-maintenance ration for beef cows during gestation resulted in a reduced rate of depletion of liver reserves and calves which weighed less at birth. A carotene deficient and/or sub-maintenance ration had no apparent effect on death loss at parturition; neither was there any indication of effect on retention of the placenta. Neither level of carotene fed the cows (27 to 30, or 126 to 150 mg. per head daily) was sufficient to prevent avitaminosis A in the calves when they were three months of age. Data on the calves showed that their blood and liver vitamin A contents did not reflect either the level of carotene supplementation or plane of nutrition of their dams, although cows on the adequate ration

produced heavier calves at three months of age.

The addition of approximately one pound of alfalfa hay or dehydrated alfalfa meal resulted in increased weight gains when added to a basal ration of cottonseed meal, milo and low-carotene sorghum silage for fattening steer calves. When the carotene in the silage was relatively high, additions of either alfalfa hay or dehydrated alfalfa meal had no effect on steer performance. The addition of more than one pound of alfalfa hay or the protein-equivalent amount of dehydrated alfalfa did not appear necessary to prevent clinical symptoms of vitamin A deficiency in steers fed 165 days; likewise, there was little difference in daily gains or blood and liver vitamin A levels between steers fed dehydrated alfalfa meal or alfalfa hay.

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A P P E N D I X

TABLE 12

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

Cow No.	Cows						Calves	
	5 mo. Prepartum		Parturition		3 mo. Post Partum		3 mo. of Age	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
				Lot I				
01	11	220	0	66	8	13	2.1	5.1
02	15	505	16	271	6	114	2.4	1.2
07	13	320	0	67	8	109	2.1	1.6
23	24	215	8	36				
63	22	312	14	150	6	18	0.7	0.5
86	14	294	7	73				
Av.	16	311	8	110	7	64	1.8	2.1
				Lot II				
5	14	587	9	54	6	19	0.3	0.4
08	5	300	0	57	8	28	0.7	10.3
42	12	395	19	111	6	16	4.7	1.4
54	17	314	6	86				
84	7	162	2	7	4	3	1.5	2.4
85	11	119	9	28				
Av.	11	313	8	57	6	16	1.8	3.6
				Lot III				
05	8	504	0	141	3	34	0.0	4.3
25	14	336	7	78	3	4	0.9	1.1
48	11	421	6	106	6	15	2.9	0.9
68	7	126	5	10				
77	12	282	5	50	5	4		
89	10	284	7	45				
96	10	239	8	190	5	28	2.9	2.6
Av.	10	317	6	89	4	17	1.7	2.2
				Lot IV				
03	22	301	5	22	8	5	2.0	2.0
04	13	195	7	73	7	20	1.5	2.1
06	7	183	0	27	10	11	1.8	2.7
7	26	460	15	121	8	29	0.7	1.0
19	10	272	4	126	7	37	1.3	3.1
46	23	411	7	77	6	23	0.0	1.5
Av.	17	304	6	74	8	21	1.2	2.1

TABLE 13

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

Cow No.	Nov.		Jan.		Feb.		Mar.		Apr.	
	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit. A	Car.	Vit.A
					Lot I					
01	87	26.5	57	18.4	31	13.8	28	27.3		
02	168	28.3	44	20.4	24	15.7	21	26.3	8	17.4
07	150	35.9	54	19.3	32	17.5				
23	87	31.3	45	20.4	34	18.2	36	21.1	18	12.2
63	159	32.1	45	22.9	24	16.6	36	28.8	25	17.8
86	144	29.0	40	18.4	21	12.0	25	22.5	10	18.1
Av.	132	30.5	48	19.9	28	15.6	29	25.2	15	16.4
					Lot II					
5	96	30.1	52	24.4	36	19.6	32	27.0	12	11.2
08	154	36.7	62	19.7	38	19.3				
42	102	37.3	50	30.3	28	22.2	28	31.0	14	23.4
54	135	32.1	38	29.8	24	21.1	15	28.1	4	16.1
84	93	25.5	33	17.8	17	11.9	19	20.9	0	9.5
85	114	31.3	40	18.1	22	13.4	26	23.4		
Av.	116	32.2	44	23.4	28	17.9	26	26.1	8	15.0
					Lot III					
05	243	30.6	123	24.2	35	16.7				
25	144	46.5	51	27.6	31	20.7	39	28.0	19	13.4
48	64	40.6	28	20.8	17	19.6	28	38.5	10	21.2
68	91	29.8	36	26.2	21	15.9	13	29.4		
77	154	32.7	34	20.7	22	16.7	38	36.2	14	14.5
89	120	37.6	40	28.0	25	21.5	50	28.7	16	13.4
96	195	39.5	44	25.1	21	23.8	33	32.2	10	19.2
Av.	144	36.8	51	24.7	25	19.3	34	32.2	14	16.3
					Lot IV					
03	210	33.1	54	26.4	32	22.9	25	22.5	10	11.1
04	147	36.1	39	32.3	23	20.2	38	34.0	8	15.4
06	282	43.4	96	21.2	54	19.3	38	25.6		
7	112	30.9	45	21.9	34	17.3	64	34.2	30	18.0
19	93	38.7	50	28.2	28	21.7	27	24.3	19	15.0
46	108	29.7	34	20.7	25	22.5	27	34.8	10	21.5
Av.	159	35.3	53	25.1	33	20.6	36	29.2	15	16.2

TABLE 14

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

Cow No.	Parturition		Lactation					
			2 Weeks		6 Weeks		3 Months	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
Lot I								
01	21	15.9	14	13.1	49	18.2	25	12.7
02	9	24.1	16	15.3	14	16.4	20	18.8
07	26	19.9	32	22.9	42	20.0	40	16.3
23	19	11.7	14	11.2				
63	25	16.5	38	15.6	45	20.4	17	12.8
86	3	11.5	19	11.2	19	15.1		
Av.	17	16.6	22	14.9	34	18.0	26	15.2
Lot II								
5	16	16.3	47	7.1	72	19.4	63	21.5
08	25	28.7	105	29.3	123	28.5	68	26.8
42	19	10.3	87	16.7	70	25.2	66	26.5
54	18	16.1	10	11.0	34	18.8		
84	10	6.8	27	7.0	62	14.1	49	11.8
85	50	23.6	28	10.6	75	22.8		
Av.	23	17.0	51	13.6	73	21.5	62	21.6
Lot III								
05	58	27.1	42	20.0	3	18.7	44	23.0
25	16	9.6	20	8.4	17	9.5	27	14.5
48	19	13.1	9	9.2	10	11.9	19	17.0
68	3	9.1	25	10.8	33	19.3		
77	33	14.0	14	15.2	16	11.5	21	10.7
89	24	14.0	34	12.0	15	15.3		
96	20	7.5	32	16.1	31	21.0	28	17.3
Av.	25	13.5	25	13.1	18	15.3	28	16.5
Lot IV								
03	14	6.1	7	4.8	21	5.5	50	16.5
04	18	17.0	52	18.3	69	21.1	77	23.6
06	39	20.3	89	22.1	187	28.6	99	22.8
7	23	17.1	66	19.4	60	22.7	48	17.8
19	19	13.1	93	16.7	62	21.7	75	21.2
46	12	12.3	50	13.7	46	15.0	55	20.2
Av.	21	14.3	60	15.8	74	19.1	67	20.4

TABLE 15

Body Weight of Cows During Gestation and Lactation in Experiment I (pounds)

Cow No.	Gestation					Partur-ition	Lactation		
	Nov.	Jan.	Feb.	Mar.	Apr.		2 wks.	6 wks.	3 mo.
Lot I									
01	815	820	820	790		700	705	715	700
02	940	910	905	835	945	755	785	795	830
07	925	880	860				735	695	715
23	655	660	640	620	700	540	560		
63	570	545	550	535	575	540	480	495	500
86	675	630	640	600	705	570	575		
Lot II									
5	770	785	790	720	760	620	615	675	690
08	800	740	745			615	605	660	690
42	630	625	615	570	620	540	535	555	560
54	775	765	765	715	775	645	630	670	
84	800	775	765	725	790	635	630	640	650
85	815	765	760	720		665	665	740	
Lot III									
05	905	880	855			820	855	855	890
25	750	735	750	730	765	610	615	670	675
48	675	680	680	700	750	605	655	645	665
68	845	860	875	905		735	740	840	
77	695	690	705	715	785	680	725	785	770
89	640	630	650	665	720	585	615	640	
96	825	825	835	830	825	735	725	785	860
Lot IV									
03	800	820	820	855	900	770	755	810	800
04	825	865	885	900	935	825	850	925	920
06	735	750	745	735		685	700	755	780
7	590	595	610	630	685	610	605	685	635
19	765	750	755	700	765	690	695	750	755
46	630	660	660	695	710	600	635	685	655

TABLE 16

Vitamin A Content of Colostrum and Milk of Cows at Intervals During Experiment I
(mcg./100 ml.)

Cow No.	Colostrum	2 Weeks	6 Weeks	3 Months
		Lot I		
01	168.6	6.6	1.8	1.8
02	36.5	6.4	4.8	5.9
07	10.2	8.2	2.0	5.4
23	85.7	9.0		
63	29.5	1.8	7.4	4.3
86	8.7	2.9		
Av.	56.5	5.8	4.0	4.4
		Lot II		
5	7.5	4.2	3.7	4.5
08	25.5	7.0	3.3	4.5
42	148.9	3.8	4.5	3.6
54	50.9	2.0	4.5	
84	32.0	8.2	7.4	3.6
85	31.2	4.0	6.2	
Av.	49.3	4.9	4.9	4.0
		Lot III		
05	22.5	7.5	11.0	4.8
25	35.0	7.4	3.6	15.2
48	143.8	2.7	2.2	8.3
68	9.9	4.3	11.3	
89	122.9	8.5	1.4	
96	27.1	25.1	4.0	5.0
Av.	69.7	8.2	5.2	7.4
		Lot IV		
03	1.1	15.0	10.2	6.8
04	39.4	6.8	4.8	5.0
06	6.4	4.6	2.8	6.6
7	12.0	4.0	1.0	4.5
19	81.0	7.3	4.7	4.3
46	27.1	3.1	7.5	5.7
Av.	27.8	6.8	5.2	5.5

TABLE 17

Plasma Carotene and Vitamin A Content of the Blood of Calves at Intervals from Birth to Three Months of Age in Experiment I (mcg./100 ml.)

Dam No.	Birth		2 Weeks		6 Weeks		3 Months	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
				Lot I				
01	3.9	6.8	0.0	18.0	15.3	13.9	17.4	9.5
02	1.5	9.3	0.0	12.7	0.0	5.8	15.9	8.7
07	0.0	15.5	15.8	19.5	2.3	15.8	17.4	8.6
23	0.0	4.0	10.0	7.3	died			
63	6.0	5.8	13.5	7.1	3.0	5.0	8.1	
86	14.4	16.4	7.2	5.3	died			
Av.	4.3	9.6	7.8	11.6	5.2	10.1	14.7	8.9
				Lot II				
5	4.5	7.6	4.5	14.3	7.2	6.6	7.2	5.3
08	3.0	13.0	10.5	17.6	3.0	11.5	17.4	10.8
42	0.0	6.2	0.0	4.4	7.2	6.6	14.4	7.9
54	6.0	8.6	1.5	7.0	6.0	6.7	died	
84	4.5	7.7	0.0	6.2		6.0	11.4	8.1
85	7.2	9.3	3.0	6.0	9.0	8.3	died	
Av.	4.2	8.7	3.2	9.2	6.5	7.6	12.6	8.0
				Lot III				
05	0.0	8.1	6.0	19.8	0.0	6.2	15.3	11.5
25	0.0	4.9	3.0	5.1	3.0	6.0	9.0	6.0
48	9.0	10.2	1.5	8.4	4.5	9.6	9.0	7.4
68	0.0	6.2	0.0	5.3	3.0	5.6	died	
89	0.0	12.2	10.5	10.1	1.5	7.0	died	
96	3.0	6.0	3.9	12.9	0.0	9.0	13.5	7.0
Av.	2.0	7.9	4.2	10.3	2.0	7.2	11.7	8.0
				Lot IV				
03	9.0	7.4	14.4	7.9	8.1	8.4	9.9	4.6
04	0.0	6.2	3.9	18.2	1.5	7.0	18.3	10.4
06	0.0	7.6	7.2	17.9	15.9	9.7	36.0	10.4
7	3.9	6.9	7.2	8.1	6.0	13.2	9.9	5.5
19	3.9	4.6	1.5	5.7	0.0	8.1	11.4	6.7
46	0.0	4.4	11.4	9.5	3.0	8.3	15.9	8.3
Av	2.8	6.2	7.6	11.2	5.8	9.1	16.9	7.6

TABLE 18

Body Weight of the Calves and Gain from Birth to Three Months of Age in Experiment I (pounds)

Dam No.	Sex	Body Weight				Gain
		Birth	2 Weeks	6 Weeks	3 mo.	Birth to 3 mo.
			Lot I			
01	F	58	77	105	160	102
02	F	71	75	80	115	44
07	F	66	80	125	190	124
23	M	61	60	died		
63	M	41	47	45	45	4
86	M	62	55	died		
			Lot II			
5	F	56	60	70	95	39
08	F	63	79	105	140	77
42	F	43	50	60	95	52
54	F	55	50	50	died	
84	M	58	60	80	105	47
85	F	52	58	60	died	
			Lot III			
05	F	65	93	150	230	165
25	M	65	70	80	95	30
48	F	64	70	95	130	66
68	F	69	75	80	died	
89	M	64	80	90	died	
96	M	75	95	110	165	90
			Lot IV			
03	M	66	70	95	135	69
04	M	67	100	130	190	123
06	F	65	85	125	195	130
7	M	49	60	85	110	61
19	F	58	75	80	130	72
46	F	68	70	105	150	82

TABLE 19

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

Cow No.	Cows						Calves	
	5 mo. Prepartum		Parturition		12 Weeks Post Partum		12 Weeks	
	Car.	Vit.A	Car.	Vit. A	Car.	Vit. A	Car.	Vit.A
				Lot I				
19	27	496	10	158	6	63	2.6	2.0
32	24	344	8	135	6	86	0.0	0.7
54	24	594	9	244	6	177	1.0	3.3
76	16	168	7	51	4	9	0.0	0.4
86	22	239	9	201	23	147	2.4	2.0
96	25	535	10	230	13	154	0.8	0.4
Av.	23	396	9	170	10	106	1.1	1.5
				Lot II				
34	28	804	18	316	35	440	1.0	1.4
40	41	643	9	225	11	135	0.0	5.1
41	33	285	12	126	14	79	0.0	trace
45	31	266	6	57	14	42	2.6	0.5
84	21	534	8	211	24	152	0.9	1.2
91	20	300	8	108	10	72	0.0	1.7
Av.	29	472	10	174	18	153	0.8	1.6
				Lot III				
12	26	568	8	175	5	44	1.1	0.7
27	31	534	10	163	9	86	0.6	2.1
47	50	746	11	178	16	224	0.6	2.9
49	30	449	9	115	10	44	2.1	0.2
51	18	297	5	46	12	11	1.0	0.5
74	21	182	5	24	5	8	2.6	2.3
Av.	29	463	8	117	10	70	1.3	1.4
				Lot IV				
7	21	268	5	32	21	47	3.2	1.1
26	36	518	5	25	11	22	2.5	0.5
50	26	598	7	151	13	146	1.0	5.1
70	28	480	30	204	28	146	0.4	9.7
81	16	333	4	58	14	30	0.7	1.5
87	19	260	26	134	16	95	2.5	2.3
Av.	24	410	13	101	17	81	1.7	3.4

TABLE 20

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

Cow No.	Nov.		Jan.		Feb.		Apr.	
	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A
				Lot I				
19	570	40.0	99	25.6	46	23.9	81	27.5
32	420	40.5	66	22.3	54	17.3	86	23.9
54	339	36.5	71	26.1	32	24.9	39	26.5
76	261	37.4	68	22.7	36	22.6	77	20.6
86	303	30.7	103	19.6	46	20.9	82	18.1
96	279	36.1	68	24.3	35	20.2	77	22.1
Av.	362	36.9	79	23.4	42	21.6	74	23.1
				Lot II				
34	285	33.3	34	18.8	21	24.8	36	24.6
40	387	34.7	58	23.5	36	20.6	63	20.5
41	399	35.7	68	24.8	62	21.7	158	35.3
45	336	35.4	63	24.6	22	20.7	44	18.1
84	249	39.6	60	21.6	19	20.9	42	23.1
91	300	34.5	100	32.4	31	23.1	63	28.6
Av.	326	35.5	62	24.3	32	22.0	68	25.0
				Lot III				
12	282	33.5	33	26.7	31	28.2	75	34.7
27	315	29.7	70	32.6	34	24.8	59	15.8
47	567	23.5	123	27.2	36	24.7	89	25.3
49	310	31.3	60	29.0	28	22.3	114	22.3
51	403	31.6	69	28.9	32	20.0	34	17.8
74	465	16.5	66	24.9	30	19.6	116	18.5
Av.	390	27.7	70	28.2	32	23.3	81	22.4
				Lot IV				
7	336	40.5	60	30.6	30	23.1	58	20.1
26	450	45.1	58	20.0	23	20.6	63	21.5
50	475	35.7	110	27.9	33	23.8	46	28.6
70	381	30.8	70	27.3	33	26.9	480	51.2
81	310	30.1	66	27.5	27	22.3	248	38.6
87	328	36.0	72	32.4	36	19.6	327	57.2
Av.	380	36.4	73	27.6	30	22.7	204	36.2

TABLE 21

Plasma Carotene and Vitamin A Content of the Blood of Cows at Parturition and During Lactation in Experiment II (mcg./100 ml.)

Cow No.	Parturition		Lactation					
			2 Weeks		6 Weeks		12 Weeks	
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A
				Lot I				
19	97	18.7	86	18.6	91	23.9	85	19.9
32	73	11.7	59	12.0	69	18.4	72	17.9
54	44	15.7	68	19.1	98	27.8	74	24.4
76	62	17.2	62	14.5	55	16.2	63	13.7
86	66	12.6	71	14.3	90	23.6	89	17.6
96	57	16.2	51	12.3	52	21.3	58	24.1
Av.	66	15.4	66	15.1	76	21.9	74	19.6
				Lot II				
34	38	12.9	165	17.5	207	28.8	144	30.3
40	87	11.2	167	16.0	193	20.9	273	28.9
41	109	14.2	143	23.2	179	20.8	165	23.7
45	26	14.0	125	16.5	171	17.9	160	18.3
84	36	12.9	142	14.0	165	21.5	232	28.0
91	45	13.1	98	15.0	198	22.5	184	25.0
Av.	57	13.0	140	17.0	186	22.1	193	25.7
				Lot III				
12	88	21.3	58	26.1	92	29.3	80	17.3
27	66	13.8	60	17.9	90	24.2	100	19.2
47	60	14.7	105	17.7	132	26.3	130	29.1
49	46	14.7	59	17.1	71	21.0	86	17.8
51	32	10.7	43	18.0	71	18.5	68	16.3
74	55	13.6	68	14.4	95	17.7	98	16.0
Av.	58	14.8	66	18.5	92	22.8	94	19.3
				Lot IV				
7	40	13.9	152	17.3	250	26.0	265	20.5
26	26	11.4	154	21.3	169	24.0	154	18.2
50	37	16.1	192	17.8	219	32.4	342	33.1
70	484	23.4	313	19.1	393	27.5	294	23.8
81	62	14.1	164	22.5	226	27.3	283	32.2
87	275	18.7	180	24.4	226	26.7	264	17.2
Av.	154	16.3	192	20.4	247	27.3	267	24.2

TABLE 22

Body Weight of Cows During Gestation and Lactation in Experiment II (pounds)

Cow No.	Gestation					Partur-ition	Lactation		
	Nov.	Dec.	Jan.	Feb.	Apr.		2 wks.	6 wks.	12 wks.
					Lot I				
19	680	705	645	615	610	520	590	580	600
32	800	800	740	715	745	650	675	685	690
54	690	675	625	605	640	585	590	610	640
76	625	630	595	565	610	550	525	550	545
86	830	870	830	795	840	730	770	765	790
96	675	695	620	610	630	550	520	605	570
Av.	717	729	676	651	679	598	612	632	639
					Lot II				
34	720	695	625	610	670	575	560	585	600
40	755	785	700	725	765	680	675	690	685
41	740	735	640	650	645	620	625	605	645
45	815	835	755	720	760	670	635	675	685
84	750	785	710	700	750	650	660	680	690
91	735	705	645	655	705	615	595	620	645
Av.	752	757	679	677	716	635	625	642	658
					Lot III				
12	760	750	715	785	785	705	740	775	805
27	690	705	720	780	795	645	715	700	715
47	735	740	750	780	760	625	645	680	695
49	715	735	725	740	750	630	710	735	760
51	790	815	790	865	880	735	775	875	835
74	750	800	710	760	770	675	745	750	790
Av.	740	758	735	785	790	692	722	752	767
					Lot IV				
7	800	795	750	855	865	735	790	765	780
26	775	750	735	800	790	690	725	770	790
50	700	665	630	660	715	630	660	645	650
70	680	690	645	710	720	605	635	620	630
81	865	860	830	890	925	820	855	870	870
87	785	815	795	825	830	765	795	850	860
Av.	768	762	731	790	808	708	743	753	763

TABLE 23

Carotene and Vitamin A Content of Colostrum and Twelve-week Milk Sample, and Estimated Daily Milk Production and Vitamin A Output After Twelve Weeks of Lactation in Experiment II

Cow No.	Colostrum (mcg. %)		12 Weeks (mcg. %)		Daily Milk Production (ml.)	Milk Vit. A Per Day (mcg.%)
	Car.	Vit. A	Car.	Vit. A		
			Lot I			
19	23.4	86.8	2.2	4.5	980	44
32	71.6	136.5	1.5	3.2	1080	35
54	64.6	204.6	3.8	3.5	1000	35
76	65.0	217.0	4.0	1.7	960	16
86	13.3	49.0	1.5	1.0	1520	15
96	117.1	247.0	4.0	8.0	175	14
Av.	59.2	156.8	2.8	3.6	950	26
			Lot II			
34	26.1	74.8	5.2	0.5	660	3
40	17.4	77.8	5.2	5.0	1960	98
41	51.8	81.6	4.6	1.8	890	16
45	17.2	88.6	3.7	0.6	1000	6
84	16.4	85.8	2.1	1.6	870	14
91	29.2	78.5	2.4	2.2	1200	26
Av.	26.4	81.2	3.9	2.0	1100	27
			Lot III			
12	109.0	342.0	3.8	1.3	1140	14
27	46.3	135.6	2.2	1.8	1660	30
47	25.2	56.7	3.6	1.3	1000	13
49	75.0	240.0	3.6	trace	1280	
51	5.6	11.8	1.5	0.4	2600	10
74	26.7	33.4	3.8	1.1	1820	20
Av.	47.9	136.6	3.1	1.0	1560	14
			Lot IV			
7	13.8	28.6	3.0	0.7	2700	19
26			3.8	0.7	1370	10
50	5.2	20.3	5.2	2.3	1300	30
70	110.0	55.7	3.8	1.4	1360	19
81	11.0	8.8	3.2	0.8	2200	18
87	47.8	36.4	4.8	1.8	1200	22
Av.	37.6	29.9	4.0	1.3	1680	20

TABLE 24

Plasma Carotene and Vitamin A Content of the Blood of Calves at Intervals from Birth to Twelve Weeks of Age in Experiment II (mcg./100 ml.)

Dam No.	Birth		2 Weeks		6 Weeks		12 Weeks	
	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A	Car.	Vit.A
				Lot I				
19	0.0	5.0	10.1	15.6	9.2	13.8	8.1	2.5
32	0.0	4.4	11.5	9.2	11.2	10.2	9.9	2.8
54	0.0	5.0	4.5	8.2	8.9	6.3	7.2	3.1
76	1.5	4.2	4.8	7.6	11.0	10.9	10.5	1.0
86	0.0	11.7	8.7	7.8	10.5	8.7	7.2	1.3
96	0.0	8.9	8.5	13.5	8.1	11.2	4.5	5.0
Av.	0.2	6.5	8.0	10.3	9.8	10.2	7.9	2.6
				Lot II				
34	0.0	6.6	6.8	10.9	14.4	11.6	8.1	2.1
40	0.0	8.9	13.2	17.2	13.1	14.9	11.4	6.3
41	0.0	6.6	4.4	8.6	6.4	7.4	7.2	1.3
45	0.0	6.6	4.1	10.9	14.4	7.9	1.5	trace
84	0.0	7.8	4.7	12.0	9.0	8.3	3.0	1.5
91	0.0	7.8	4.5	8.1	11.4	8.1	7.2	2.2
Av.	0.0	7.4	6.3	11.3	11.4	9.7	6.4	2.2
				Lot III				
12	1.5	5.5	1.2	8.9	9.9	7.3	9.9	2.8
27	0.0	6.6	6.0	7.7	11.4	6.7	10.5	2.3
47	6.7	6.4	5.5	8.2	14.4	15.5	7.2	4.8
49	1.5	5.5	6.4	8.5	9.9	6.0	7.2	1.3
51	0.9	6.5	4.7	9.1	13.5	7.0	3.0	2.9
74	5.4	8.1	4.5	5.5	9.0	8.3	7.2	3.5
Av.	2.7	6.4	4.7	8.0	11.3	8.5	7.5	2.9
				Lot IV				
7	6.2	8.0	10.2	9.5	24.9	14.6	7.2	3.1
26	1.5	8.9	10.5	8.2	11.4	8.6	10.5	2.8
50	0.0	5.5	0.9	9.9	11.4	10.0	3.9	2.4
70	0.0	7.3	16.5	9.7	14.4	10.7	13.5	8.0
81	1.5	9.8	10.5	12.1	15.3	7.8	12.3	4.9
87	0.0	8.9	12.9	12.6	14.4	11.6	0.9	3.0
Av.	1.5	8.1	10.2	10.3	15.3	10.6	8.0	4.0

TABLE 25

Body Weight of the Calves and Gain from Birth to Twelve Weeks of Age in Experiment II (pounds)

Dam No.	Sex	Body Weight				Gain
		Birth	2 Weeks	6 Weeks	12 Weeks	Birth to 12 Weeks
				Lot I		
19	M	60	62	85	145	85
32	M	60	75	100	130	70
54	F	50	65	90	130	80
76	F	65	60	80	105	55
86	F	47	75	100	150	85
96	F	55	52	70	95	48
Av.			65	88	126	70
				Lot II		
34	F	55	65	95	130	75
40	M	65	75	110	165	100
41	F	55	60	75	130	75
45	F	53	65	85	105	52
84	F	55	70	95	135	80
91	F	55	65	87	130	75
Av.		56	67	91	132	76
				Lot III		
12	F	50	70	100	140	90
27	M	68	82	120	195	127
47	M	60	65	100	150	90
49	F	72	75	95	115	43
51	M	67	83	125	180	113
74	F	60	65	85	130	70
Av.		63	73	104	152	89
				Lot IV		
7	M	70	85	130	190	120
26	M	68	77	110	135	67
50	F	60	65	90	130	70
70	F	65	90	130	195	130
81	M	73	100	125	195	122
87	F	60	85	120	155	95
Av.		66	84	118	168	101

TABLE 26

Plasma and Liver Carotene and Vitamin A and Average Daily Gain of Steers in 1953

Steer No.	Blood (mcg.%)		Liver (mcg./gm. dry)		Average Daily Gain (lb.)
	Car.	Vit. A	Car.	Vit. A	
			Lot I		
5	84	22.6	6.1	4.5	2.44
8	66	19.6	4.7	2.3	2.09
11	78	21.9	5.8	7.2	2.20
32	102	22.7	5.3	2.6	2.56
41	78	18.9	6.0	2.1	2.27
51	87	23.5	4.7	2.6	2.06
54	93	19.8	4.3	2.9	2.20
56	99	15.8	4.4	1.3	2.56
80	54	22.3	3.6	4.5	1.96
86	66	17.7	4.0	2.6	2.09
Av.	81	20.5	4.9	3.3	2.24
			Lot V		
14	10	8.3	1.4	0.8	2.19
24	18	10.3	2.7	1.2	2.28
28	5	6.8	0.9	0.8	1.67
34	12	7.9	1.8	1.7	2.16
59	11	8.3	1.1	0.9	2.13
63	10	4.6	1.1	0.2	2.38
73	14	7.8	2.2	0.8	2.07
75	9	8.5	1.0	0.4	2.12
76	8	7.1	1.3	0.6	1.56
81	5	7.2	2.2	0.9	1.78
Av.	10	7.7	1.6	0.9	2.03
			Lot VI		
3	45	12.9	3.3	2.3	2.34
6	30	11.9	2.3	2.8	2.48
13	26	12.7	2.7	2.1	2.21
39	57	18.2	3.4	3.0	2.41
43	51	16.0	3.9	2.6	2.25
47	30	11.9	2.3	2.8	2.12
60	30	11.0	3.0	1.3	2.35
69	57	18.9	3.0	2.4	2.15
71	23	11.9	2.3	1.5	2.41
74	48	23.6	3.6	2.3	1.88
Av.	40	15.1	3.0	2.2	2.26

TABLE 27

Plasma and Liver Carotene and Vitamin A and Average Daily Gain of Steers in 1954

Steer No.	Blood (mcg.%) Oct. Car.	Jan. Car.	Jan. Vit. A	Apr. Car.	Apr. Vit. A	Liver (mcg./gm.dry) Car.	Liver Vit. A	Average Daily Gain (lb.)
				Lot I				
8	88	30	21.1	10	18.1	0.0	2.8	2.20
9	39	28	20.3	21	16.3	0.0	2.7	2.02
16	48	16	13.8	14	10.6	0.0	1.2	1.66
21	171	28	21.7	19	14.1	0.0	1.7	1.66
26	51	48	18.2	28	12.8	0.0	1.3	1.99
28	42	32	9.3	17	7.6	0.0	1.0	1.78
35	279	39	19.8	23	13.4	0.0	1.4	1.69
62	132	40	14.4	36	17.5	2.6	3.1	2.41
91	112	35	11.5	27	12.1	0.0	0.8	1.69
97	66	31	3.8	23	12.4	0.0	1.0	1.78
Av.	103	33	15.4	22	13.5	0.3	1.7	1.88
				Lot II				
3	148	72	24.0	17	27.6	9.2	1.4	1.81
36	75	51	20.4	37	24.6	7.4	4.8	1.81
38	106	48	21.2	55	15.4	42.4	4.0	1.72
49	178	74	25.4	51	25.9	5.4	3.3	2.44
60	61	72	23.0	77	27.8	16.7	3.2	1.96
67	76	56	20.1	69	25.8	0.0	3.0	1.93
68	107	32	18.4	54	22.1	45.5	3.6	2.17
74	52	36	17.6	38	24.0	4.4	1.3	1.96
84	104	38	12.2	42	14.2	2.3	3.9	1.93
103	75	70	18.4	70	23.9	4.3	4.7	1.75
Av.	98	55	20.1	51	23.2	13.8	3.3	1.95
				Lot III				
5	94	63	30.5	46	32.3	4.5	3.5	2.23
20	58	86	23.5	48	22.2	3.3	0.4	2.11
33		57	22.5	57	29.1	4.0	4.0	1.99
41	135	62	19.1	50	23.6	3.6	3.4	2.05
43	37	26	11.2	36	16.7	11.6	3.8	2.08
59	171	98	25.1	79	28.7	4.3	3.6	2.17
66	85	62	16.2	45	21.0	17.4	6.2	1.66
69	66	52	19.9	39	19.4	3.1	2.8	1.96
83	60	75	13.8	43	17.1	17.4	6.2	2.23
Av.	90	67	19.8	39	23.3	7.8	3.8	2.05

TABLE 27 (Continued)

Steer No.	Blood (mcg.%) Oct. Car.	Jan. Car.	Jan. Vit. A	Apr Car.	Apr Vit. A	(mcg./gm.dry) Car.	(mcg./gm.dry) Vit. A	Average Daily Gain (lb.)
				Lot IV				
10	42	54	23.8	69	18.1	5.9	8.2	2.29
11	96	51	20.9	5	22.5	4.9	4.2	1.87
12	207	69	24.7	86	26.7	4.6	4.5	1.99
14	66	55	21.6	77	23.1	0.4	4.6	2.26
27	117	66	16.8	71	27.1	6.7	27.0	1.69
30	168	50	16.5	121	35.5	18.9	7.6	2.14
48	54	40	31.1	66	30.2	5.6	11.6	2.20
50	75	88	15.7	118	33.3	17.4	7.3	2.35
71	84	76	20.0	75	26.9	9.6	6.1	2.02
96	97	100	28.1	78	30.8	5.1	0.4	2.23
Av.	101	65	21.9	77	27.4	7.9	8.2	2.10
				Lot V				
1	104	75	21.2	88	28.7	6.1	4.7	2.02
7		98	25.1	81	28.7	3.0	2.5	2.47
32	211	11	22.0	102	26.3	5.5	2.4	1.99
37	102	46	15.0	38	21.5	4.9	0.4	1.90
44	243	77	21.0	118	36.6	5.6	13.2	2.47
54	66	100	22.3	79	23.4	7.9	7.4	1.81
80	130	39	9.2	66	27.0	4.4	3.8	2.29
85	42	56	32.0	79	30.2	6.8	9.9	2.17
90	132	163	21.1	201	41.5	6.7	7.9	1.93
102	91	125	25.2	93	30.0	5.6	7.6	2.20
Av.	124	79	21.4	94	29.4	5.6	6.0	2.12
				Lot VI				
31	69	114	22.3	120	25.4	11.4	7.4	2.20
51	106	83	24.5	118	27.8	6.5	3.3	1.75
58		206	21.1	237	34.5	11.0	22.9	2.86
70	83	114	26.0	165	36.5	8.9	39.8	2.08
75	213	100	15.2	186	30.5	11.3	39.1	2.11
76	60	134	17.1	123	30.6	8.7	4.2	2.05
77	81	105	23.5	98	36.0	8.8	7.7	2.35
78	104	89	9.7	133	37.8	5.1	9.6	1.99
100	104	234	21.6	213	41.2	14.1	13.2	2.02
101	63	105	27.7	60	30.6			1.81
Av.	98	128	20.9	145	33.1	9.5	16.4	2.12

TABLE 28

Plasma and Liver Carotene and Vitamin A and Average Daily Gain of Steers in 1955

Steer No.	Blood (mcg. %)						Liver (mcg./gm.dry)		Average Daily Gain (lb.)
	October		January		April				
	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	Car.	Vit. A	
					Lot I				
4	61	27.8	36	16.7	54	20.3	3.8	2.3	2.15
5	186	28.1	61	17.7	71	14.1	3.7	6.0	2.42
10	131	33.5	44	15.1	66	18.3	4.7	4.3	2.42
43	183	38.0	74	23.8	59	20.9	4.3	2.9	2.79
75	128	25.9	30	14.3	43	16.1	4.0	1.3	2.12
80	116	39.1	54	28.5	85	25.1	5.2	1.6	2.36
86	88	28.0	39	21.4	62	17.7	2.8	1.4	2.02
92	92	37.7	60	30.1	50	25.6	3.2	1.5	2.42
100	121	27.6	45	12.2	54	11.9	5.0	1.8	2.06
120	213	26.0	32	16.9	62	14.7	5.2	0.3	2.15
Av.	132	31.2	48	19.7	60	18.5	4.2	2.3	2.29
					Lot II				
9	163	32.1	95	29.6	128	31.4	4.3	1.8	2.56
14	55	34.8	51	34.0	79	30.2	5.5	4.7	2.48
15	207	38.5	69	31.6	71	27.3	4.6	1.7	2.09
19	77	24.6	51	21.4	39	16.4	3.0	1.0	1.84
26	105	29.9	86	22.3	125	24.6	4.9	1.1	2.64
31	103	27.5	83	32.7	87	22.3	6.4	3.2	2.33
89	71	32.5	60	26.9	90	24.7	3.9	1.9	2.27
97	172	29.1	66	20.3	79	25.9	5.4	10.6	2.45
113	123	29.6	90	36.6	111	30.6	4.7	6.4	2.45
Av.	120	30.9	72	28.4	90	25.9	4.7	3.6	2.35
					Lot III				
1	116	25.8	66	22.3	100	26.0	7.2	4.8	2.73
27	77	29.4	66	18.3	81	22.3	5.5	1.6	2.27
32	100	29.4	64	23.6	92	20.3	6.8	1.7	2.09
34	187	31.4	75	24.8	114	26.0	6.3	5.4	2.27
40	85	26.0	33	31.1	36	20.6	4.6	10.0	1.84
59	154	35.6	75	21.7	63	19.6	6.7	2.4	2.06
70	121	35.9	80	28.1	54	23.4	6.9	4.2	2.30
73	92	23.6	42	31.5	42	23.6	5.3	4.4	2.70
87	121	26.5	62	24.8	119	16.7	5.9	2.1	2.48
106	168	32.2	81	29.9	63	22.1	5.8	2.3	2.42
Av.	122	29.6	64	25.6	76	22.1	6.1	3.9	2.34

TABLE 28 (Continued)

Steer No.	Blood (mcg. %) October Car.	Oct. Vit. A	January Car.	Jan. Vit. A	April Car.	April Vit. A	Liver (mcg./gm.dry) Car.	Liver Vit. A	Average Daily Gain (lb.)
				Lot IV					
3	137	32.4	56	24.3	39	24.7	6.1	3.4	2.27
11	105	24.5	50	19.6	59	23.5	4.8	5.5	2.09
16	103	28.4	60	18.7	82	22.1	7.3	4.2	1.75
25	80	23.4	43	15.2	66	24.4	6.9	6.2	2.36
49	125	30.6	59	21.9	72	25.0	3.6	1.7	2.30
67	79	22.4	62	21.6	123	26.3	6.4	2.1	2.24
85	71	17.9	66	17.8	83	22.6	8.2	4.9	2.48
91	130	42.1	89	23.8	103	45.1	6.0	1.2	2.36
102	98	34.9	62	22.2	79	28.1	7.1	6.1	2.39
115	119	30.0	86	19.3	95	27.5	5.8	4.5	1.72
Av.	105	28.7	63	20.4	80	26.9	6.2	3.9	2.25
				Lot V					
17	135	31.3	90	20.5	105	21.0	5.7	1.8	2.45
21	61	25.8	39	8.3	39	17.4	3.4	2.8	2.36
42	80	28.1	83	13.1	83	20.5	3.4	24.2	1.93
56	88	26.0	98	24.1	131	25.8	5.1	3.7	2.48
60	71	34.7	87	24.9	116	23.7	5.3	13.7	1.90
76	71	34.1	66	14.9	68	23.3	4.5	14.0	2.21
78	186	30.8	58	22.0	62	27.7	6.1	5.0	2.55
81	182	24.2	88	13.6	89	17.1	6.8	1.1	2.27
83	93	18.7	54	11.4	93	20.3	5.9	3.9	2.09
101	71	33.6	60	16.7	75	14.8	4.6	2.5	2.39
Av.	104	28.7	72	17.0	86	21.2	5.1	7.3	2.26
				Lot VI					
12	154	33.8	135	31.9	100	23.4	6.2	2.9	2.12
22	144	28.0	87	22.4	105	23.5	6.9	4.8	2.27
23	306	50.6	165	44.8	213	36.4	10.9	10.2	2.21
38	144	28.0	87	11.8	86	20.8	7.7	6.2	2.36
48	106	33.1	141	31.6	130	23.7	8.1	1.9	2.12
51	121	35.3	158	34.7	151	28.5	7.5	1.8	1.87
62	70	29.3	123	18.4	103	19.5	6.3	1.3	2.42
72	156	41.1	76	37.7	88	20.7	7.3	2.2	1.99
93	121	35.3	128	32.5	137	27.4	8.3	3.9	2.30
111	90	26.8	154	36.7	123	31.8	6.4	6.2	2.48
Av.	141	34.1	125	30.2	124	25.6	7.6	4.1	2.25

TABLE 28 (Continued)

Steer No.	Blood (mcg. %) October Car.	Vit. A	January Car.	Vit. A	April Car.	Vit. A	Liver (mcg./gm.dry) Car.	Vit. A	Average Daily Gain (lb.)
				Lot VII					
8	95	37.4	56	27.8	116	24.8	3.8	2.0	2.52
28	145	41.6	55	10.4	36	16.7	3.9	2.6	2.39
30	122	35.2	58	19.5	108	26.4	4.2	2.3	2.45
36	83	30.5	34	26.9	34	14.4	3.0	1.2	2.02
37	90	27.9	36	15.7	36	15.7	4.4	4.8	2.21
52	111	35.0	31	16.6	32	18.9	3.9	1.3	1.84
54	86	25.9	45	19.0	85	18.3	4.1	1.4	2.27
69	110	29.5	56	5.7	63	13.6	5.8	1.2	2.21
96	135	23.8	80	23.4	92	15.8	2.6	1.1	2.09
Av.	109	31.9	50	18.3	67	18.3	4.0	2.0	2.22
				Lot VIII					
20			44	25.6	81	23.3	4.5	1.1	2.15
35			62	21.7	65	19.9	5.1	2.3	1.96
58			75	23.8	106	19.7	4.9	2.0	2.30
74			70	30.4	103	24.2	4.5	3.6	2.36
84			56	22.1	72	15.9	3.2	1.7	2.56
88			47	10.1	58	16.0	4.7	3.5	2.09
99			62	9.0	70	17.7	4.1	1.4	2.18
105			69	10.8	53	19.3	3.3	3.0	2.52
117			72	24.9	122	26.5	6.8	3.3	2.45
118			19	12.2	30	13.3	3.7	2.1	2.12
Av.			58	19.1	76	19.6	4.5	2.4	2.28

TABLE 29

Average Carotene Content of Alfalfa Hay and Pellets and Sorghum Silage for 1953, 1954 and 1955

Feed	Carotene (mg./lb.)		
	1953	1954	1955
Alfalfa Hay	16.7	14.5	16.7
Dehydrated Alfalfa Pellets		25.3	12.7
Lot III Pellets			7.5
Lot V Pellets			8.8
Sorghum Silage	0.44	1.4	2.8

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