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# VITAMIN A STUDIES IN FATTENING FEEDER CALVES AND YEARLINGS

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It has been shown in vitamin A studies in fattening feeder cattle that fattening rations may sometimes be deficient in vitamin A.

Vitamin A deficiency is characterized by night blindness. In later stages the cattle become less alert, may water at the eyes, show nasal discharge, suffer from solar heat, show body swelling, become day blind, lose appetite and weight, develop rough, dry hair coat, and die unless the condition is relieved.

Farm animals are supplied vitamin A largely through carotene in grasses, hays and silage. Carotene is formed only in plants and is associated with green color. Grazing animals are able to change carotene to vitamin A which process takes place in the liver. Green grasses and legumes, leafy green new crop legume hays, and cod or other fish liver oil, all high in vitamin A potency, will protect fattening cattle from vitamin A deficiency or will remedy the condition if it has been allowed to occur.

The vitamin A and carotene content of the liver, blood and fat is related to the quantity of carotene in the feed and the length of time such feed has been consumed. Feeder cattle removed from dry range during droughts become depleted of vitamin A reserves more quickly than those removed from green range. Young animals become depleted more quickly than older ones from the same range.

Carotene in the ration has no effect upon gain or fattening as long as there are body reserves of carotene and vitamin A, nor does an abundance of carotene increase gain after the minimum amount required to maintain health is fed. The minimum of carotene for the maintenance of health was approximately 2000 to 2500 micrograms daily per 100 pounds live weight although 1500 micrograms allowed satisfactory fattening of the steers in spite of minor symptoms of vitamin A deficiency.

In dry lot fattening with mixtures of protein supplements, grains, cottonseed hulls or weathered roughages, carotene supplements are usually not needed for the first 50 to 100 days. To guard against losses from vitamin A deficiency one can observe the cattle for night blindness after 50 days. If night blindness is observed the cattle may be fed 1 to 3 pounds of good green alfalfa hay or other green roughage per head daily, or instead of waiting for the onset of night blindness feed 1 to 2 pounds of alfalfa from the start.

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# VITAMIN A STUDIES IN FATTENING FEEDER CALVES AND YEARLINGS

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Vitamin A is recognized as one of the essential vitamins necessary for the maintenance of life. Plants furnish it to animals in the form of carotene, a precursor of vitamin A. Insufficiency of vitamin A, when continued long enough, leads to serious disturbances of health, blindness, or even death. Figure 1 shows a steer which was fed a ration deficient in carotene until seriously affected by vitamin A deficiency. The steer became permanently blind but regained good condition when alfalfa, which supplies carotene, was added to his ration.

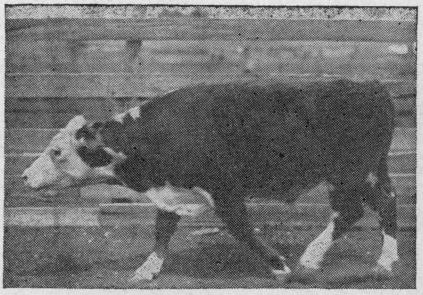

**Figure 1. This steer, although remaining totally blind as a result of vitamin A deficiency, regained good condition upon being supplied with carotene in dehydrated alfalfa leaf meal.**

Disorders in fattening cattle, now known to be caused by vitamin A deficiency, were described before that vitamin was discovered. Such disorders were once associated with the use of rations in which protein supplements were fed without grain along with roughages of poor quality. Among early investigators to study this problem were Connell and Carson (1), Burns and Metcalfe (2), and Curtis (3) and (4). It was not until 1930 that Halverson and Sherwood (5), collaborators of Curtis in the work started at the North Carolina Station (3) in 1908, reported work showing that the major factor involved in injury to steers fed long periods in dry lot on cottonseed meal and cottonseed hulls was a vitamin A deficiency. This was

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confirmed by this Station with an experiment started in 1934 and first reported (6) (31) in 1935. That experiment and succeeding experiments are now presented although reports on different phases of the study have been published (7) (8) (9) by the Texas Station workers.

The work reported here was planned in cooperation with the Bureau of Animal Industry, U. S. Department of Agriculture, in 1935, following the completion of a feeding test begun in November, 1934. In that test, hereafter referred to as Experiment 1, a group of weaned steer calves were fed on a ration consisting of cottonseed meal, white grain sorghum grain and cottonseed hulls; while other groups were fed the same mixture of feeds with the addition of various amounts of ground alfalfa hay. The following spring a group which did not receive alfalfa developed disorders which Schmidt (9) found to be caused by vitamin A deficiency. The groups which received alfalfa did not develop such disorders.

The experiments were planned to determine: (1) the quantity of carotene required in fattening feeder calves and yearlings, (2) the conditions under which vitamin A deficiency may occur, and (3) practical means of prevention and correction of such deficiency in fattening cattle.

## PROCEDURE

Except in the first experiment the general plan was to feed a ration low in carotene until night blindness occurred and then to feed, upon the basis of body weight, supplementary test levels of carotene supplied by ground alfalfa hay or dehydrated alfalfa leaf meal. This method of feeding carotene according to body weight was based upon the hypothesis advanced in 1935 by Guilbert and Hart (10), that the vitamin A requirement is proportional to body weight. The above plan provided for two rather distinct periods of feeding: (1) the period of depletion of body reserves of vitamin A, and (2) the period of testing the levels of carotene. The rations fed during the period required for depletion of body reserves of vitamin A, as indicated by the occurrence of night blindness, were calculated to maintain good condition and rate of gain without producing finish. The depletion period was used to equalize, insofar as possible, the individual body reserves of vitamin A prior to the test period. After depletion, grain was added to the rations in quantities sufficient for the production of marketable finish.

### Cattle Used

Ten separate groups of feeder cattle comprising 370 head have been used. They were, in the main, Good to Choice Hereford feeders taken directly from ranges in Dickens County to the feedlots at Substation No. 7, Spur, Texas. Although several days usually passed between the date the cattle were received and the date the experiment was started they were, in all instances, maintained on rations low in carotene during such periods. With the exception of one group of calves obtained in March and another group in September, the cattle were received about November 1. Table 1 lists the cattle used.

**Table 1. Feeder cattle used in these experiments**

| Expt. No. | Year | No. of animals | Class | Age in months | Average initial weight pounds | Date of delivery | Days of Prel. Feeding | Date Test Started |
|---|---|---|---|---|---|---|---|---|
| 1 | 1934-35 | 40 | Steer calves | 6-8 | 406 | Nov. 2, 1934 | 33 | Dec. 5, 1934 |
| 2 | 1935-36 | 48 | Steer yearlings | 16 | 559 | Oct. 15, 1935 | 30 | Nov. 14, 1935 |
| 3 | 1936-37 | 50 | Steer calves | 6-8 | 469 | Nov. 23, 1936 | 16 | Dec. 9, 1936 |
| 4 | 1937-38 | 50 | Steer calves | 6-8 | 448 | Nov. 12, 1937 | 6 | Nov. 18, 1937 |
| 5 | 1938-39 | 50 | Steer calves | 6-8 | 464 | Nov. 7, 1938 | 24 | Dec. 1, 1938 |
| 6 | 1939-40 | 40 | Heifer calves | 4-6 | 330 | Oct. 25, 1939 | 28 | Nov. 22, 1939 |
| 7 | 1940-41 | 50 | Steer calves | 4-6 | 268 | Sept. 9, 1940 | 9 | Sept. 18, 1940 |
| 8* | 1938-39 | 10 | Steer calves | 4-6 | 289 | Oct. 28, 1938 | -- | Oct. 28, 1938 |
| 9* | 1939 | 12 | Steer calves | 3-5 | 246 | Mar. 17, 1939 | -- | Mar. 17, 1939 |
| 10* | 1939-40 | 20 | Steer calves | 3-5 | 225 | Oct. 25, 1939 | -- | Oct. 25, 1939 |

*Used in study of time required for depletion only.

## Feeds Used

The feed mixtures for both depletion and fattening are shown in Table 2.

**Table 2. Percentage composition of low-carotene feed mixtures used**

| Experiment No. | Year | Composition of rations per cwt. | | | | |
|---|---|---|---|---|---|---|
| | | Cottonseed meal | Cottonseed hulls | Sorghum grain | Tankage | Sorghum fodder |
| | Depletion rations | | | | | |
| 1 | 1934-35 | 11 | 78 | 11 | -- | -- |
| 2 | 1935-36 | 12 | 88 | -- | -- | -- |
| 3 | 1936-37 | 10 | 87 | -- | 3 | -- |
| 4 | 1937-38 | 10 | 87 | -- | 3 | -- |
| 5 | 1938-39 | 10 | 87 | -- | 3 | -- |
| 6 | 1939-40 | 15 | 52 | 30* | 3 | -- |
| 7 | 1940-41 | 10 | 69 | 18* | 3 | -- |
| 8† | 1938-39 | 13 | -- | 38* | -- | 49 |
| 9† | 1939 | 12.5 | 62.5 | 25* | -- | -- |
| 10† | 1939-40 | 15 | -- | 28* | -- | 57 |
| | Fattening rations | | | | | |
| 1 | 1934-35 | 11 | 78 | 11 | -- | -- |
| 2 | 1935-36 | 15 | 55 | 30 | -- | -- |
| 3 | 1936-37 | 15 | 52 | 30 | 3 | -- |
| 4 | 1937-38 | 15 | 52 | 30 | 3 | -- |
| 5 | 1938-39 | 15 | 52 | 30 | 3 | -- |
| 6 | 1939-40 | 15 | 35 | 45* | 3 | -- |
| 7 | 1940-41 | 15 | 43 | 38* | 3 | -- |

*Fed ground milo heads.
†Used in study of time required for depletion only.

The 43% protein cottonseed meal and the cottonseed hulls used were of prime quality and were purchased locally. The tankage which was fed was newly processed 60% protein digester tankage. The ground threshed grain sorghum grains fed in Experiments 1, 2, 3, 4 and 5 and ground milo heads fed in Experiments 6, 7, 8, 9 and 10 were of

good quality and were locally produced. These grains, ranging in carotene content from 0.3 to 0.69 microgram per gram, supplied small amounts of carotene when fed in large quantities. Ground alfalfa hay, also of local origin, was used to supply carotene in the first four experiments; but dehydrated alfalfa leaf meal was used in the succeeding experiments. Curative agents, as cod liver oil, pure crystalline carotene dissolved in maize oil, fresh green alfalfa, and fresh green sudan grass were used in instances of advanced vitamin A deficiency in Experiments 1 and 3. Cottonseed hulls were used as the sole roughage in all test rations except in Experiments 8 and 10 in which sorghum fodder having a carotene content of about 4 micrograms per gram was used and in Experiment 9 in which sorghum fodder containing 2 micrograms of carotene per gram was fed during the first 58 days.

### Methods of Feeding and Treatment

All of the principal feeds were mixed together on the percentage basis shown in Table 2. The mixtures were fed twice daily in the amounts that would be consumed. Pulverized limestone was fed at the rate of 0.10 pound per head daily in Experiments 3, 4, 5 and 7. Salt was fed free choice except in Experiment 6 in which 1 percent of salt was added to the feed mixture.

During the depletion period the cattle were group fed except in Experiment 6 in which they were individually fed. In all experiments except the first they were individually fed during the fattening or test period in which the various carotene levels were supplied.

In Experiment 1, all lots except one received ground alfalfa and all lots received grain from the outset. In the second and third experiments the cattle were placed in individual pens and were started on a fattening grain ration and a given carotene level as they successively reached depletion. In Experiments 4, 5, 6 and 7 the first cattle to become depleted were placed upon a carotene level of 800 micrograms per 100 pounds live weight daily until a sufficient number became depleted to form the various test groups. The fattening rations and the given carotene levels were then begun for all animals at the same time.

Except for Experiment 1, alfalfa meal or dehydrated alfalfa leaf meal was fed to supply a stated number of micrograms of pure carotene per 100 pounds live weight daily. The carotene level was kept adjusted to the live weight by means of weekly weighings of the animals and weekly or bi-weekly determinations of the pure carotene content of the alfalfa. The carotene content of the alfalfa was reported in parts per million.

The allowance of alfalfa for each animal was weighed daily to the nearest gram. In order to insure complete consumption, the alfalfa was fed with about 2 pounds of the regular feed mixture early in the morning, and when it had been cleaned up the balance of the morning feed was given.

### Measure of Night Blindness

Since night blindness is the first noticeable symptom to develop in the syndrome of vitamin A deficiency this symptom was used as a guide in determining when the animals were depleted of their body reserves of vitamin A. Two consecutive observations of a recognizable degree of night blindness or other definite assurance of vitamin A deficiency were considered evidence of depletion. In a few cases the observers were unable to determine the degree of night blindness but other symptoms afforded evidence of depletion.

The animals were tested for night blindness out-of-doors after twilight by driving them back and forth through 8-foot alleys in which were located movable panel barriers of wood either unpainted or painted black on one side and white on the other. With continued depletion the animals appeared to become progressively more night blind, finally becoming completely night blind in nearly all cases. As a result, night blindness or affected night vision was measured by the judgment of the observer and expressed in degrees as follows: 0—normal, no indication of defective night vision; 1°—cautious, but can see objects at least 5 feet away; 2°—cautious, but can see objects 2 feet away; 3°—totally night blind.

The reaction of night blind cattle to different intensities of light was observed on numerous occasions by using a flood light controlled with a theatre dimmer; however, this light was not used in routine testing. Animals which were completely night blind were able to find their way with little difficulty when the light was too dim to be measured by a Weston photographic light meter and when it appeared as only a low orange-red glow on the ground. Moonlight apparently did not particularly aid the night blind cattle to see but flashes of lightning aided vision and affected the accuracy of routine night blindness tests.

The different years of work identified as separate experiments are mentioned only as the results from them contribute to the principal findings. Attention has been given to the general manifestations of vitamin A deficiency in fattening cattle, the time required for depletion of body reserves of vitamin A, and the effect of feeding various carotene levels upon night blindness, health, gain and the carotene content of livers, blood plasma and fat.

## GENERAL MANIFESTATIONS OF VITAMIN A DEFICIENCY IN FATTENING CATTLE

### Symptoms and Gross Pathology of Vitamin A Deficiency

On a ration deficient in vitamin A and after the depletion of body reserves of vitamin A, symptoms of vitamin A deficiency appear and gradually progress in severity until death occurs. The first indication of a vitamin A deficiency in cattle is the appearance of night blindness. When checking the cattle in semi-darkness one will observe as a rule that the animal when approaching an obstacle will suddenly stop and veer

in order to avoid it. It acts as though it had suddenly discovered the obstacle, although normally it should have recognized it from a much greater distance. As time goes on this night blindness becomes gradually and progressively intensified until the animal becomes totally blind. Low degrees of night blindness may be present and continue for several weeks during which time the actual degree is difficult to determine, but sooner or later the condition will progress to total night blindness perhaps within as short a time as one week. At this stage the animal shows normal vision during the day but if carotene is not supplied the condition may progress to so-called day blindness in one or both eyes and manifested by total permanent blindness in the affected eye or eyes with a maximum dilatation of the pupil. In cases of permanent blindness in both eyes the animal shows a characteristic cautious walk in which the nose is carried higher and a little more forward than normally, see Figure 1, often with audible breathing as though the animal were sniffing the breeze. In case blindness is present only in one eye, the head is held in a peculiar "cocked" position, see Figure 2, with the blind eye side tilted slightly upwards.

**Figure 2. Steer 80 from Experiment 3. permanently day blind in left eye. Note abnormal carriage of the head.**

Symptoms we now consider as due to vitamin A deficiency were observed in ancient times. Thus the statement (11) "and the wild asses did stand in the high places, they snuffed up the wind like dragons; their eyes did fail; because there was no grass" is peculiarly descriptive of a vitamin A deficiency. An involvment of the eye was recognized in the condition known as "fat sickness" by Connell and Carson (1). Curtis (3) listed the symptoms observed in some cattle fed only cottonseed meal and cottonseed hulls as: affected eyesight, temporary or possibly permanent blindness, weakness followed by staggers, fits or spasms, swellings, failure of conception and respiratory troubles. Guilbert and Hart (10) observed the occurrence of blindness among cattle fed diets deficient in carotene and found night blindness to be the first detectable symptom of vitamin A deficiency. Many other workers have reported upon the involvment of the eye in vitamin A deficiency as Moore (12). Hale (13) (14) established the fact that maternal vitamin A deficiency may result in a variety of defects in the offspring, including abnormally small eyes at birth and, with other Texas workers, observed such small eyes among pigs and calves born under farm conditions following the severe drouth of 1934. In one particular dairy herd the dry cows were fed a ration low in carotene during the winter of 1934-35. Ten of the 15 calves dropped in the spring of 1935 were blind.

Before the stage of day blindness is reached the eyes usually show other affections such as watering, Figure 3, with or without inflammatory signs of the mucous membranes and the cornea may and often does show opacity. This opacity varies markedly in extent and degree, usually beginning with one or two whitish specks the size of a pin head and may progress until the whole cornea is involved and ulceration sets in. In the early stages of opacity no inflammatory reaction is present, but as the condition progresses such reaction sets in and may become quite intense and the eyes protrude more than normally. Such opacities of the eyes are especially prevalent in calves and yearlings and may be entirely absent in mature animals.

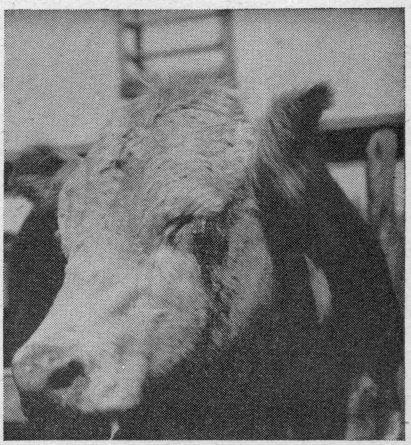


**Figure 3. Another symptom of vitamin A deficiency: swollen eyes with profuse lacrimation, also nasal discharge. Such eye cases may be confused with infectious keratitis. This steer was day blind 2 weeks after the picture was taken; however, day blindness does not necessarily follow such eye condition.**

Following the onset of night blindness a lack of normal alertness, Figure 4, is usually one of the early symptoms that can be observed. At this first stage of droopy condition the animal does not necessarily go off feed or show other marked evidence of vitamin A deficiency.

Convulsions is one of the symptoms observed in many cases and sometimes appears before affection of the eye becomes noticeable or before any other symptoms, with the exception of night blindness, are present. They appear suddenly with or without apparent provocation. The animal suddenly sways or staggers, Figure 5, for a few seconds, drops to the ground and lies flat on its side with legs extended, the muscles rigid and breathing suspended. This seizure lasts for about one-half minute when the animal suddenly lets out a long audible breath, relaxes its muscles and gets up as though nothing had happened.

When the condition has progressed to the point of complete night blindness or affection of the eyes has set in, other symptoms become apparent such as a more or less marked nasal discharge and suffering from solar heat manifested by the saliva being beaten into a foam, which may drop to the ground in large quantities, and accelerated respiration which may progress to panting with protruding tongue, Figure 6. This panting was observed only in the summertime during the heat of the day, even though the animal was in the shade. When during this time the animal is forced from the shade into the sun it makes frantic efforts to reach shade again.

Edematous infiltration of the tissues also appears about this time, which becomes visible externally in the form of swellings. These are most readily recognized when the skin rests upon a solid foundation such as bones or thin layers of muscles and thus first become manifest on the legs in the region between the upper limits of the hock and the foot. Naturally they may include any part of the body and may therefore be seen in the region of the thigh, shoulder, and neck, Figure 7. These swellings do not necessarily remain uniform in extent and degree once they appear but rather vary in intensity from day to day or week to week, especially when the ration is not completely devoid of carotene. A harsh, dry hair coat and an unpliable skin may also develop.

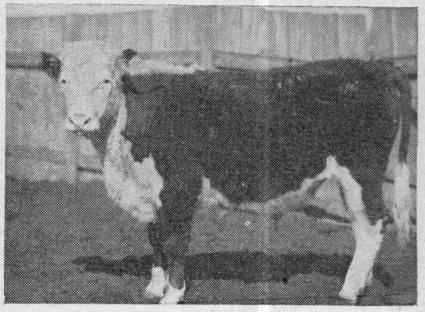


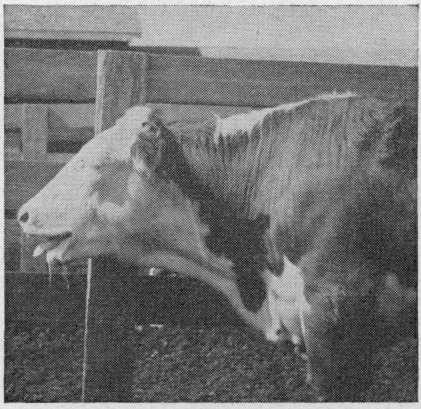
**Figure 4.** **Upper—Steer 63, Experiment 2, March 9, 1936, alert but at this time was completely night blind. Lower—the same steer on April 10. Note lack of normal alertness, typical of vitamin A deficiency and following night blindness one of the early symptoms usually observed.**

The symptoms enumerated above appear one after the other, sometimes rapidly, sometimes slowly, but develop in intensity as the depletion of body reserves of vitamin A progresses. A serious stage is finally reached, Figure 7, in which the animal refuses feed, loses weight, and appears very dejected. In this stage the animal may still be saved by the administration of carotene or vitamin A as supplied in readily available form such as cod or other fish liver oil. If this is not given the animal will soon die.

**Figure 5.** **Steer just before falling to the ground with a convulsion.**

At autopsy one finds grossly the condition of the eye already visible during life. The hide is more difficult to remove than normally, mostly due to the fact that the subcutaneous tissue, at the places where it is not edematous, is dry and tough. At the points of visible swellings the subcutaneous tissues show edematous infiltration which may be very extensive. Infiltration located more deeply may also be found at points where no swelling was vis-

ible externally and thus occur in the connective tissue between the muscles of almost any part of the body and the musculature is much moister than normally so that fluid may drip from a freshly made cut. In the intestinal tract a marked congestion of the mucosa may be found. An increased amount of fluid may also be found in the pericardial sac and in the subdural space. The spleen may be smaller than normal and rather dry. In case of day blindness a degeneration of the optic nerve may be far enough advanced to be recognized grossly.



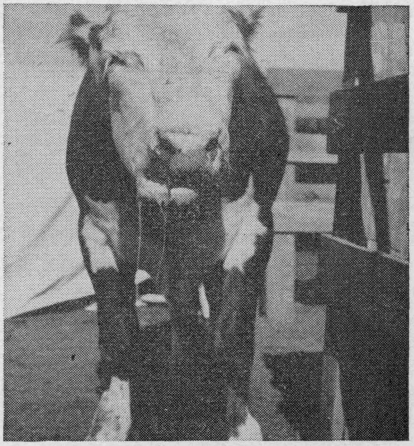


**Figure 6** **A steer affected by vitamin A deficiency may suffer from solar heat more than normal animals. Note protruding tongue and marked nasal discharge and slobbering. This steer was restored to normal condition by dosage with cod liver oil.**

### Effect of Long Continued Feeding on Low Carotene Level

The effect of the long continued feeding of a carotene level insufficient to maintain life on feed consumption, gain and fattening was observed with 5 steers from Experiment 3, 1936-37, which were removed from Spur to College Station in May 1937. The ten 469-pound steer calves originally involved in this test were started on depletion ration in November 1936. They were the first 10 to become depleted out of the 50 head used in Experiment 3. Following their depletion, as indicated by night blindness, in March 1937 they were fed 450 micrograms of carotene supplied by dehydrated alfalfa leaf meal per 100 pounds live weight daily. They were fed the 450 microgram level until they either died or were sacrificed in extremis. The performance of these steers is summarized in Table 3.

Two of the steers lived approximately 5 months, two more than one year, and one more than 2½ years on the 450 microgram level. In connection with the report of Keener and associates (15) that an increased amount of carotene seems to be required in severe winter weather it is

noted that 4 of the 5 steers in this group died during the warm months and the other died prior to the advent of cold weather.

The steers consumed more than three pounds of the basal feed mixture per 100 pounds live weight daily prior to their transfer to College Station and continued to consume good amounts during the next four or five weeks after their transfer. The deficiency then became more evident and all showed marked loss of appetite. Numbers 84 and 97 died at about this time but the others improved in appetite and seemed to get along quite well for 6 to 7 months when they again became seriously affected, lost appetite and weight and Numbers 80 and 96 died. At this time it was difficult to tell which of the steers was most seriously affected but Number 99 rallied and lived about 18 months longer.

The rate of gain continued upward, but at slow rate after depletion, except for the periods when there was loss of appetite. Much of the loss of weight shown for such periods was caused by lack of fill. All of the steers became quite fat, Figure 8, showing that the ability of the animal to store fat was not impaired by the carotene deficiency in the ration except as appetite was impaired. Steer 99 became fat, as shown in Figure 9 (upper), but later lost flesh as shown at the end of 730 days; however he again regained fair condition before he died after 993 days on the 450 microgram level. These steers showed the typical symptoms of vitamin A deficiency as previously described. It was quite evident from this work and from other work at Spur from 1934 to 1937

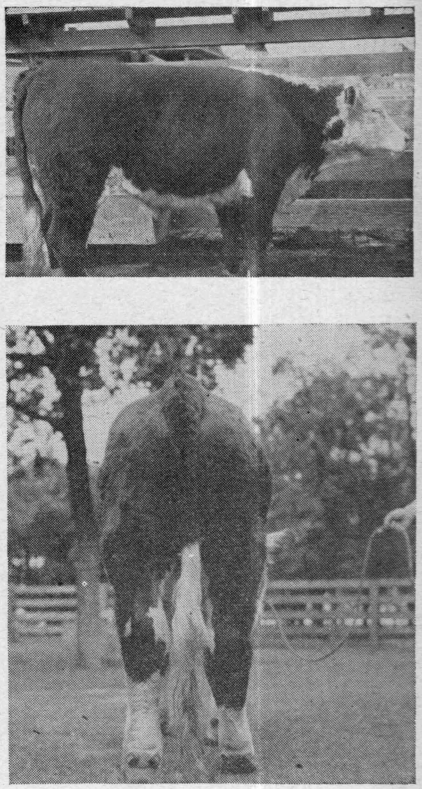


**Figure 7.** **Upper—Steer 44, Experiment 2, 1935-36. This steer although not day blind, had roughened dry hair coat, was stiff and sluggish, had scant appetite and showed marked edema in the shoulder region. He had subsisted upon a ration low in carotene for 381 days, was in an advanced stage of depletion, and his carcass was condemned. Lower—Steer 96, Experiment 3, 1936-37, after 471 days on 450 microgram carotene level. This steer was down and unable to rise the following day and was sacrificed. Note swellings of legs.**

**Table 3. Performance of steers on 450 microgram carotene level, Experiment 3**

| Steer No. | Date started on depletion ration | Died | Days in experiment | Days required for depletion | Days on carotene level | Gain in experiment, lbs. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total | Daily |
| 84 | Nov. 23, 1936 | July 27, 1937 | 246 | 101 | 145 | 421 | 1.71 |
| 97 | Nov. 23, 1936 | Aug. 12, 1937 | 262 | 108 | 154 | 326 | 1.24 |
| 96 | Nov. 23, 1936 | June 26, 1938* | 580 | 108 | 472 | 498 | .86 |
| 80 | Nov. 23, 1936 | July 9, 1938 | 600 | 115 | 485 | 513 | .86 |
| 99 | Nov. 23, 1936 | Nov. 29, 1939† | 1102 | 108 | 993 | 746 | .68 |

*Sacrificed in extremis.
†Sacrificed because of urethral occlusion caused by urinary calculi.

that less carotene is required for feedlot gain than for the maintenance of health.

### Effect of Various Treatments

Curative treatments consisted in increasing the quantity of vitamin A potency in the ration through the use of green growing feeds, alfalfa hay or alfalfa leaf meal high in carotene; or through the use of cod or other fish liver oils, high in Vitamin A.

In Experiments 1 and 3 steers affected by vitamin A deficiency were given various curative treatments. In the first instance the treatments were designed to identify the condition which had resulted from feeding weaned steer calves a mixture of cottonseed meal, ground threshed white grain sorghum grain, and cottonseed hulls, which condition had not resulted in similar groups of calves fed the same basal mixture but fed in addition 1, 2½ and 5 pounds of alfalfa hay per head daily. In the second instance the treatments were employed to insure the marketability of fattened steers since rather severe deficiency had been allowed to develop in them in testing low carotene levels. The treatments given to the 10 steers, Lot 1, Experiment 1, 1934-35, are shown in Table 4.

Cod liver oil given as a drench

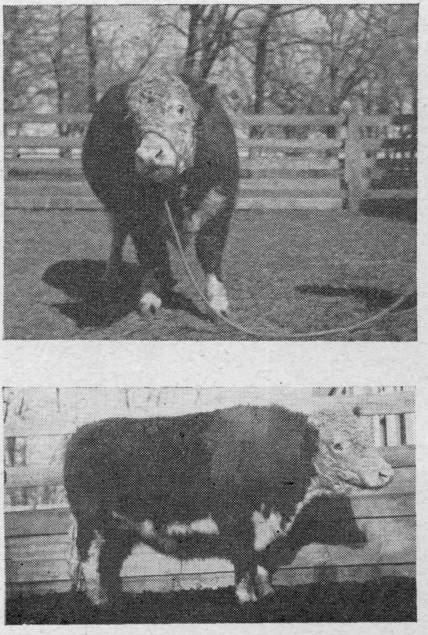


**Figure 8. Steer No 80 lived for 485 days on the 450 microgram level including the depletion period. The pictures show him after 320 days of feeding on this level. The high finish and abnormal head carriage are evident.**

in 25cc and 50cc doses daily to 3 steers suffering from vitamin A deficiency effected definite improvement in condition in 15 days and there was some improvement in 7 days. One steer given 10cc of cod liver oil daily improved in general condition in 15 days but remained night blind.

The cod liver oil used in these treatments was registered for a potency of 500 units of vitamin A per gram, but upon assay showed 550 Sherman-Munsell rat units. Upon the latter basis the two steers which were fed 50cc of cod liver oil received 3400 units of vitamin A per 100 pounds live weight daily; the one fed 25cc, 1575 units; and the one fed 10cc, 620 units.

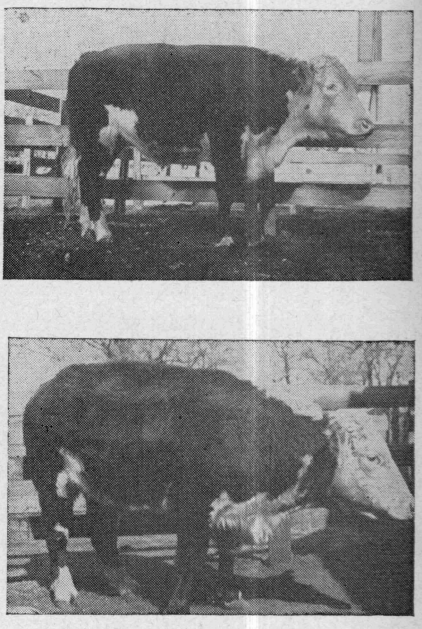


**Figure 9. Steer No. 99 lived for 993 days on the 450 microgram carotene level and 1102 days including the depletion period. The pictures show him after 320 and 730 days (upper and lower respectively) of feeding on this level.**

One steer was given 10cc and another 25cc daily of pure crystalline carotene (having 5000 International Units per gram) dissolved in maize oil. Both steers improved in condition as quickly as the steers given cod liver oil. The one given 25cc of carotene daily was treated for only 14 days and made spectacular recovery, but was again droopy and sluggish 30 days after the treatment was discontinued. The steer given 10cc daily for 40 days while showing improvement did not completely recover from labored breathing.

Aerated cod liver oil, that is cod liver oil in which the vitamin A had been destroyed by heat and oxidation, fed in doses of 25cc and 50cc daily completely failed to correct the condition which had been found. One-half pound and one pound of alfalfa hay and one-half pound of fresh green alfalfa fed to the steers which did not improve on the aerated cod liver oil effected some improvement in condition. The steer fed one-half pound of green alfalfa improved rapidly in both night vision and general condition, but those fed the alfalfa hay made slow and only partial improvement. In fact, the steer fed one-half pound of alfalfa hay made such little improvement that it was changed to 4 pounds of fresh green sudan grass daily. Improvement occurred within 10 days after the change to sudan grass.

One steer which was continued on the basal carotene deficient mixture and which was not given a vitamin A or carotene supplement died on the

**Table 4. Treatment of vitamin A deficient steers, Experiment 1, 1934-35, on basal ration of cottonseed meal, cottonseed hulls, and white grain sorghum grain**

| Steer No. | Before affected: Days on ration | Before affected: Daily gain, lbs. | Date affected | Wt. loss prior to improvement, lbs. | Daily Treatment: Date started | Daily Treatment | Daily Treatment: Date stopped | Daily Treatment: Days to improve | Remarks on July 22 |
|---|---|---|---|---|---|---|---|---|---|
| 35 | 116 | 2.01 | April 1 | 26 | May 6 | 50cc cod liver oil | July 17 | 15 | Normal |
| 19 | 124 | 1.87 | April 8 | 27 | May 6 | 50cc cod liver oil | July 17 | 15 | Normal |
| 39 | 124 | 1.78 | April 8 | 61 | May 6 | 25cc cod liver oil | July 17 | 15 | Partial recovery |
| 22 | 125 | 2.08 | April 9 | 52 | May 8 | 50cc aerated cod liver oil* | June 7 | -- | Did not improve |
| | -- | --- | -------- | -- | June 7 | ½ lb. fresh green alfalfa | July 22 | 38 | Partial recovery |
| 37 | 136 | 2.12 | April 20 | 26 | May 14 | 50cc aerated cod liver oil* | June 7 | -- | Did not improve |
| | -- | --- | -------- | -- | June 7 | 1 lb. alfalfa hay | July 17 | 36 | Partial recovery |
| 8 | 154 | 2.28 | May 8 | 55 | May 15 | 25cc aerated cod liver oil* | June 7 | -- | Did not improve |
| | -- | --- | -------- | -- | June 7 | ½ lb. alfalfa hay | July 12 | 33 | Partial recovery |
| | -- | --- | -------- | -- | July 12 | 4 lbs. fresh green sudan | July 22 | 10 | Marked improvement |
| 26 | 154 | 2.27 | May 8 | 42 | June 13 | 10cc cod liver oil | July 17 | 38 | Partial recovery |
| 15 | 154 | 2.28 | May 8 | 20 | June 7 | 10cc carotene in maize oil | July 17 | 8 | Partial recovery |
| 6 | 167 | 2.43 | May 21 | 7 | June 7 | 25cc carotene in maize oil | June 21 | 10 | Made marked improvement but again droopy |
| 29 | 140 | 2.10 | April 24 | 66 | -------- | No treatment | -------- | -- | Died after 179 days |

*Cod liver oil in which the vitamin A had been destroyed.

179th day of the experiment. This fact, together with the failure of affected steers to improve when fed the aerated cod liver oil, the improvement and recovery of affected steers when fed cod liver oil, pure crystalline carotene and feeds containing carotene and the absence of affected condition in the steers which had been fed alfalfa hay in addition to the basal mixture from the outset showed that the lack of vitamin A was the sole cause of the condition encountered in the steers fed the basal mixture of cottonseed meal, ground threshed grain sorghum grain, and cottonseed hulls.

In Experiment 3, 1936-37, various dosages of cod liver oil were given to 17 steers which showed marked symptoms of vitamin A deficiency following the supply of low levels of carotene. Dosages of 1000 to 2000 USP units of vitamin A (based upon the guarantee of the processor of the cod liver oil) daily per 100 pounds body weight were employed during a period of 29 to 43 days. Unit dosages were given daily, and at intervals of 1, 7, 15 and 30 days. The dosage given at an interval of, for example 7 days, was 7 times greater than the daily dosage or 7000 units of vitamin A per 100 pounds body weight. There was a wide difference in degree of affected condition among the steers at the start but there was some uniformity in response to treatment.

Four of 7 steers which had been supplied carotene levels of 450 to 600 micrograms following depletion improved in night vision upon dosages of 1000 to 1500 units of vitamin A daily per 100 pounds body weight. Dosages of 2000 units effected slightly greater improvement. Although the dosages of cod liver oil did not completely restore night vision in the periods of treatment involved, marked improvement in appetite and general condition followed. After a few days of treatment steers which had been sluggish and off feed became alert and anxious for their feed. Dosages given daily or at intervals of one day appeared to be equally effective. The same unit dosages

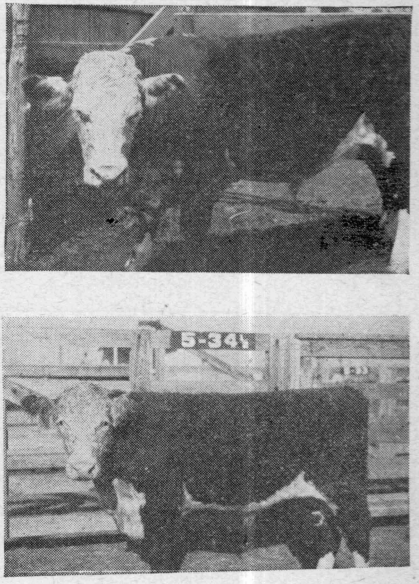



**Figure 10.** **Steer 56, Experiment 3, showing typical change in general health following restorative treatment. Upper—On 5/21 before start of treatment was sick, listless, and suffered from solar heat. Lower—At market 8/20, reasonably alert and an acceptable slaughter steer although still night blind and showing some degree of incoordination.**

given at longer intervals effected marked improvement in a few days, but the beneficial effect usually failed to last until the next treatment.

Following the treatments with cod liver oil part of the steers were kept for an additional 28 days and were fed either fresh green alfalfa or alfalfa hay free choice. An improvement in night vision resulted in all except one steer of the 12 involved in this final period of treatment. The behavior of this steer which showed complete night blindness as well as that of others which were slow to improve indicates that vitamin A deficiency may result in injury to tissues which are not readily healed even when large amounts of carotene or vitamin A are supplied. A persistent fullness at the hocks among some of the steers retained for the final period of treatment was of concern to the observers. There was no general improvement in this condition, as judged by the eye, from the treatments; however, all of the steers afforded acceptable carcasses under B.A.I. inspection. Figure 10 shows a case of improved well-being following restorative treatment.

## TIME REQUIRED FOR DEPLETION OF BODY RESERVES OF VITAMIN A IN FEEDER CATTLE IN DRY LOT

There was wide variation in the time required for depletion of vitamin A reserves as indicated by the onset of night blindness between individuals, between feeder groups of different age, and between years with feeder groups of the same approximate age and initial weight. This problem has been discussed in some detail by Riggs (8) whose report covered the present work up to 1939-40. The variation in time required for the depletion of 310 feeder cattle used in this phase of the study is shown in Table 5.

Wide variation was particularly apparent among the yearling steers used in 1935-36 in which the range was 128 to 266 days, average 178 days, and a standard deviation of 37. In contrast the widest variation found in well grown feeder steer calves of approximately 450 pounds initial weight, was 101 to 206 days with a standard deviation of 25. The least variation in the well grown steer calves was from 82 to 155 days for 1938-39; but 10 younger steer calves, with an average initial weight 289 pounds obtained at the same time became depleted in a range of 83 to 90 days. The wide differences in time required for depletion of individuals in the same year indicate that different individuals have different reserves of vitamin A in the body and suggest possible differences between individuals in ability to utilize carotene for a given function. The smaller degree of variability as well as the shorter time required for depletion of the younger animals tends to indicate a smaller storage for them than for the older animals.

The variation in time required for depletion of the feeder calves used from year to year definitely indicates a relationship between rainfall, the vitamin A potency of the range forage and the body storage of vitamin A reserves. Table 6 shows the monthly and annual rainfall at the Spur Station during the course of these experiments.

**Table 5. Time required for depletion of vitamin A reserves in 310 feeder cattle.**

| Year | 1935-36 | 1936-37 | 1937-38 | 1938-39 | 1938-39 | 1939 | 1939-40 | 1939-40 | 1940-41 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Steer yearlings | Steer calves | Steer calves | Steer calves | Steer calves | Steer calves | Heifer calves | Steer calves | Steer calves | |
| Number | 48 | 40 | 50 | 50 | 10 | 12 | 30 | 20 | 50 | 310 |
| Age in months | 16 | 6-8 | 6-8 | 6-8 | 4-6 | 3-5 | 4-6 | 3-5 | 4-6 | --- |
| Initial weight, lbs. | 559 | 469 | 448 | 464 | 289 | 246 | 330 | 225 | 268 | --- |
| Days for depletion | | | | | | | | | | |
| 45- 59 | -- | -- | -- | -- | -- | 6 | -- | -- | -- | 6 |
| 60- 74 | -- | -- | -- | -- | -- | 6 | -- | 11 | 11 | 28 |
| 75- 89 | -- | -- | -- | 10 | 10 | -- | 1 | 6 | -- | 27 |
| 90-108 | -- | 9 | 1 | 20 | -- | -- | 25 | 2 | 25 | 82 |
| 109-128 | 5 | 1 | 16 | 15 | -- | -- | 4 | 1 | 12 | 54 |
| 129-148 | 9 | 18 | 19 | 3 | -- | -- | -- | -- | 2 | 51 |
| 149-168 | 10 | 8 | 13 | 2 | -- | -- | -- | -- | -- | 33 |
| 169-188 | 5 | 2 | -- | -- | -- | -- | -- | -- | -- | 7 |
| 189-208 | 5 | 2 | 1 | -- | -- | -- | -- | -- | -- | 8 |
| 209-228 | 13 | -- | -- | -- | -- | -- | -- | -- | -- | 13 |
| 229-248 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 249-268 | 1 | -- | -- | -- | -- | -- | -- | -- | -- | 1 |
| Range | 128-266 | 101-206 | 96-194 | 82-155 | 83-90 | 46-61 | 82-112 | 65-131 | 72-134 | |
| Average | 178 | 136 | 138 | 107 | 86 | 56 | 98 | 79 | 98 | |
| Standard deviation | ±37 | ±25 | ±21 | ±21 | ±5 | ±6 | ±7 | ±17 | ±18 | |

**Table 6. Monthly and annual rainfall in inches at Spur Station, 1934-40.**

| Month | 1934 | 1935 | 1936 | 1937 | 1938 | 1939 | 1940 | Average by months |
|---|---|---|---|---|---|---|---|---|
| January | .12 | .01 | 1.11 | .38 | 1.14 | 1.98 | .16 | .70 |
| February | .21 | .61 | Trace | Trace | 3.31 | .25 | 1.14 | .79 |
| March | 2.20 | .98 | .22 | 2.05 | .82 | .52 | -- | .83 |
| April | 1.16 | .71 | 2.49 | .86 | .89 | .29 | 1.79 | 1.17 |
| May | 2.50 | 4.54 | 2.79 | 2.92 | 2.89 | 2.07 | 1.17 | 2.70 |
| June | .07 | 6.93 | 1.43 | 1.31 | 5.16 | 1.80 | 1.06 | 2.54 |
| July | .11 | .99 | 2.85 | .68 | 3.30 | .44 | .07 | 1.21 |
| August | 1.18 | 1.05 | .11 | 6.93 | .21 | 1.85 | 3.24 | 2.08 |
| September | 2.52 | 3.62 | 11.13 | 2.18 | .09 | -- | .41 | 2.85 |
| October | .87 | 2.22 | 1.41 | 2.47 | 1.33 | 2.62 | 1.34 | 1.75 |
| November | 1.93 | 1.50 | .48 | .09 | .78 | .60 | 3.16 | 1.22 |
| December | .01 | .62 | .45 | .41 | .04 | .64 | .04 | .32 |
| Total | 12.88 | 23.78 | 24.47 | 20.28 | 19.96 | 13.06 | 13.58 | 18.29 |
| July-October total | 4.68 | 7.88 | 15.50 | 12.26 | 4.93 | 4.91 | 5.06 | 7.89 |

The average time required for depletion of 450 pound feeder steer calves purchased in the fall of 1936 and the fall of 1937 was 136 and 138 days respectively. During each of these two years the July-October rainfall was relatively high. In 1938, however, when the July-October rainfall totalled only 5 inches as compared to 15 and 12 inches in the two previous years the average time for depletion of steer calves of the same approximate age and weight was only 107 days.

Heifer calves, initial weight 330 pounds, and steer calves, initial weight 225 pounds, taken from the range in the fall of 1939; and 289 and 268 pound steer calves taken from the range in the fall of 1938 and 1940 respectively required in order of mention averages of 98, 79, 86, and 98 days for depletion. The July-October rainfall averaged approximately 5 inches for those years. Ten of the heifer calves taken from the range in the fall of 1939 and fed 1000 micrograms of carotene per 100 pounds live weight daily from the outset required an average of 113 days or 15 days longer to become depleted than the group of 30 fed the depletion ration from the outset.

In a supplementary test of the time required for depletion, 12 steer calves having an average weight of 246 pounds were removed from relatively dry winter range before the spring growth of grass began and placed on a depletion ration in March 1939. Sumac fodder which had been stored two years supplied the bulk in the ration in place of cottonseed hulls. All of these calves became night blind in 61 days, the average being 56 days and the range 46 to 61 days.

Other workers have reported similar findings. Connell and Carson (1) failed to produce "fat sickness" in aged steers by feeding cottonseed meal and cottonseed hulls in a period of 180 days. Guilbert and Hart (16) reported complete night blindness in two yearling steers fed a carotene-deficient ration in approximately 250 days after their removal from conditions which afforded excellent storage of vitamin A reserves.

Mead and Reagan (17) reported the development of vitamin A deficiency in calves 1 to 3 months after the diet was changed from whole milk and grain to a concentrate mixture low in vitamin A potency. Moore (18) found that 2 calves raised to 90 days of age on whole milk and grain and then fed skim milk and low carotene grain ration became night blind, one in 38 days and the other in 63 days. Black, and associates (19) did not note any disorders among 310-pound feeder steer calves fed ground milo heads, cottonseed meal and cottonseed hulls in a 203-day fattening period. However, tests were not conducted for night blindness. Schmidt (9) has reported differences in the time required for the depletion of vitamin A reserves in ruminants. He observed that pasturage at College Station, Texas was deficient in carotene after the first killing frost and that yearling goats placed on a deficient ration at the first killing frost survived as long as those kept on ordinary winter pasturage without access to green feed of any kind for 30 days longer before being placed on the same depleting ration.

The findings in regard to the time required for depletion of body reserves of vitamin A show that older feeder cattle possess greater reserves of vitamin A than younger ones and that the condition of the range from which the feeders were removed may be expected to affect the body reserves and the consequent time required for depletion. In dry years with limited amounts of green vegetation the time required for depletion was less than in years of more abundant rainfall and consequent greater amount of green vegetation. It was evident that the onset of vitamin A deficiency may be hastened by the degree of carotene shortage in the rations fed in dry lot. It was also evident that feeders may go for considerable periods in the dry lot without suffering from vitamin A deficiency to an appreciable extent; however, such periods are not usually long enough for fattening feeder calves on carotene deficient rations. Calves may require more than 200 days for fattening and in these tests most of the feeder calves used became depleted before 120 days.

## EFFECT OF QUANTITY OF CAROTENE UPON NIGHT BLINDNESS AND RELATED SYMPTOMS OF VITAMIN A DEFICIENCY

The experimental animals used in this phase of the study were fed a ration low in carotene until they were depleted of body reserves of vitamin A, as indicated by the occurrence of night blindness.

In Experiment 2, 1935-36, as the yearling steers used became depleted they were started on a designated carotene level and fattening grain ration individually fed. The measure of depletion was at least two observations of complete night blindness for Groups 1, 2 and 3, but slightly less evidence of depletion was required for Groups 4 and 5. The first 10 steers to become depleted formed Group 1; the second 10, Group 2, and so on with the last 8 forming Group 5. Groups 1, 2, 3 and 4 were supplied in respective order approximately 200, 350, 500, and 750 micrograms of carotene from alfalfa per 100 pounds live weight daily. Group 5 was placed on a level of approximately 2400 micrograms of carotene

since the groups started on the low levels had already shown advanced symptoms of vitamin A deficiency. The carotene levels, including the carotene supplied by both alfalfa and grain, and the period of time in which they were fed are shown in Table 7.

**Table 7. Summary of Experiment 2, 1935-36.**

| Group No. | Depletion period | | | Treatment, period | | | | *Gain for experimental period, pounds | |
|---|---|---|---|---|---|---|---|---|---|
| | Days | Gain, lbs. | | Carotene level, mcg. | No. days | Gain, lbs. | | | |
| | | Total | Daily | | | Total | Daily | Total | Daily |
| 1 | 154 | 200 | 1.61 | 282<br>1751 | 30<br>169 | 24<br>238 | .84<br>1.41 | 462 | 1.43 |
| 2 | 181 | 234 | 1.55 | 386<br>1033 | 21<br>150 | 24<br>184 | 1.16<br>1.23 | 442 | 1.37 |
| 3A | 205 | 250 | 1.43 | 549 | 148 | 151 | 1.02 | 401 | 1.25 |
| 3B | 202 | 258 | 1.50 | 436<br>1301 | 41<br>112 | −15<br>143 | −.36<br>1.28 | 386 | 1.20 |
| 4 | 226 | 288 | 1.47 | 800 | 142 | 160 | 1.27 | 448 | 1.39 |
| 5 | 246 | 309 | 1.43 | 2364 | 107 | 150 | 1.40 | 459 | 1.43 |

*These data pertain only to that period when all of the animals were on experiment, a period of 322 days.

With the first groups becoming depleted in March and April the lower carotene levels were assigned to them with the idea of completing the test of these levels before the advent of hot weather, for it had been noted in the first experiment that the heat of summer intensified symptoms of vitamin A deficiency. As expected, the three lower levels proved to be inadequate for the maintenance of health and Group 1 was raised to approximately 1800 micrograms of carotene in alfalfa, Group 2 to 1000 micrograms, and the 5 most seriously affected steers in Group 3 to approximately 1300 micrograms as shown by Table 7.

Group 1 steers remained on the low carotene level an average of 30 days before their carotene level was raised to approximately 1800 micrograms in alfalfa. After the increase an average of 16 days elapsed before improvement in physical condition was noted. Seven of the 10 steers regained a marked degree of night vision after 107 days, but the other 3 became day blind 48 days after the increase in carotene level.

Group 2 steers were on a low, 386 microgram, carotene level an average of 21 days after depletion before being raised to approximately 1000 micrograms in alfalfa. They improved in physical condition and as a group regained a degree of night vision. One steer became day blind and 2 others became day blind in one eye. Six were observed in convulsions a total of 12 times with one being observed for 5 such seizures.

Group 3 steers were started on a carotene level of approximately 500 micrograms and after 41 days the 5 showing the most advanced symptoms of vitamin A deficiency were raised to approximately 1300 micrograms. Four of the steers which remained on the 500 microgram level for an average of 148 days became day blind, the other remained night blind and all showed advanced vitamin A deficiency but only two were observed for convulsions. Three of these steers which were kept for an additional month and were not marketed until November 2, 1936 were observed to suffer markedly from brief periods of cold. Suffering from cold by animals on low levels of carotene has been confirmed by Keener and associates (15). Also, 2 out of the 5 carcasses were rejected because of a generalized edema, which condition has also been reported by Creech and Madsen (20).

Of the 5 steers from Group 3 which were raised to 1300 micrograms for a period of 112 days partial improvement in night vision was certain for two, while two became day blind and the other became day blind in one eye and remained night blind in the other. A total of 15 convulsions were observed in these steers, all animals being affected, but otherwise they were not as severely affected as the ones continued on the 500 microgram level.

Group 4 steers were considered as depleted upon the basis of slightly less evidence of complete night blindness than was required for Groups 1, 2 and 3. These steers showed improvement in night vision in the 142-day test period and improved in physical condition. Three out of 5 of this group held for an additional month on the 800 microgram level showed decline in both night vision and physical condition toward the close. One convulsion was observed for this group.

Group 5 steers were started on the 2400 microgram level when only partially night blind as compared to practically complete night blindness for the other groups. These steers did not show much evidence of night blindness until after 216 days on the depletion ration and showed other symptoms of vitamin A deficiency to only slight degree. They regained normal night vision within 4 to 6 weeks after the start of the 2400 microgram level and were lively and alert at the close as compared to all other groups.

All steers fattened to a comparatively high degree except those on the 500 microgram level which were severely affected by vitamin A deficiency to the extent of going off feed. Dosages of cod liver oil supplying about 25000 USP units of vitamin A per head daily given to steers kept for a final month of feeding effected marked improvement in physical condition and in night vision in all instances, but did not have effect upon the vision of the day blind steers.

The procedure and results of Experiment 2 have been given in detail because of the extreme variation found between individuals, because a large number were severely depleted and because the results were somewhat different in regard to night blindness from those found from the use of calves in succeeding experiments. The procedures used in later experiments, particularly that of requiring only definite assurance of affected night vision, also the procedure of equalizing the degree of depletion prior to the start of test of carotene levels were based on the results of Experiment 2. The average gains for the groups are shown in Table 7, but are not discussed because of differences in group treatments.

In Experiment 3, 1935-36, Group 5, 10 steers were started on 800 micrograms of carotene per 100 pounds live weight daily at the outset. The remaining 40 steers were fed the depletion ration and the first 10 to become depleted formed Group 1 while Groups 2, 3, and 4 were formed as the steers successively reached depletion by alternate placement. The last four groups to be formed in respective numerical order were started on levels of 450, 600, 750 and 1000 micrograms of carotene. All groups became and remained night blind on these levels and a wide range of other symptoms of vitamin A deficiency developed and reached such degree of intensity that various treatments were employed.

Except for a general condition of fullness or swelling at the hocks appearing in all groups, the symptoms of vitamin A deficiency observed in this experiment were not essentially different from those found in Experiment 2. However, the symptoms were less intense since the animals were not allowed to reach such advanced stage of deficiency before the carotene levels were raised or other treatments were employed.

In Group 1 complete night blindness developed soon after the start of the 450 microgram carotene level and remained until other treatments were used. Groups 2, 3, and 4 likewise, and in succession, became more night blind but required more time and had lower average degree of night blindness and were less seriously affected by vitamin A deficiency than Group 1. Group 5 steers required 61 days longer to become depleted as indicated by night blindness than the average for the other four groups and when their carotene level was raised from 800 to 2000 micrograms quickly regained normal night vision. Groups 2, 3, and 4 regained normal night vision following the supply of alfalfa hay free choice, but Group 1 which had been more seriously depleted than the others did not entirely regain normal night vision before the close. The cod liver oil treatments which were used have been described under the discussion of curative treatments for vitamin A deficiency. There was improvement in night blindness following the treatments with cod liver oil, however, these treatments were not continued very long and rather small amounts were allowed.

Experiments 4, 5, 6 and 7 involved the study of higher levels of carotene than Experiments 2 and 3. Feeder calves were used and the test periods were for 140 days after depletion; except for Experiment 6, with

a test period of 100 days. The observations for degree of night blindness and convulsions resulting from the several carotene levels used in the four experiments are summarized in Table 8.

**Table 8. Degrees of night blindness shown for various carotene levels fed after depletion.**

| Experiment | Carotene Level Mcg. | Number of animals and degrees of night blindness | | | | | | Convulsions |
|---|---|---|---|---|---|---|---|---|
| | | Degrees at beginning | | | Degrees at end | | | |
| | | 1° | 2° | 3° | 1° | 2° | 3° | |
| 4 | 800 | 2 | 3 | 2 | 0 | 0 | 7 | 0 |
| | 1000 | 3 | 4 | 0 | 0 | 3 | 4 | 0 |
| 1937-38 | 1250 | 2 | 4 | 1 | 0 | 1 | 6 | 0 |
| 140 days | 1500 | 4 | 2 | 1 | 2 | 4 | 2 | 0 |
| | 2000 | 2 | 4 | 1 | 0 | 6 | 1 | 0 |
| 5 | 800 | 1 | 3 | 4 | 0 | 0 | 8 | 23 |
| | 1000 | 1 | 5 | 2 | 0 | 0 | 8 | 5 |
| 1938-39 | 1250 | 2 | 4 | 2 | 0 | 1 | 7 | 1 |
| 140 days | 1500 | 1 | 4 | 3 | 0 | 1 | 7 | 1 |
| | 2500 | 0 | 5 | 3 | 0 | 6 | 2 | 0 |
| 6 | 800 | 5 | 2 | 3 | 0 | 0 | 10 | 3 |
| | 1000 | 1 | 4 | 5 | 0 | 0 | 10 | 2 |
| 1939-40 | 1500 | 1 | 2 | 7 | 0 | 1 | 9 | staggers* |
| 100 days | 1000 | 3 | 2 | 4 | 0 | 0 | 9 | 2 |
| 7 | 1250 | 6 | 2 | 0 | 0 | 1 | 7 | 2 |
| | 1500 | 3 | 5 | 0 | 0 | 3 | 5 | 1 |
| 1940-41 | 2500 | 6 | 2 | 0 | 3 | 4 | 1 | 0 |
| 140 days | 3000 | 4 | 4 | 0 | 3 | 3 | 1 | 0 |
| | 5000 | 4 | 4 | 0 | 3 | 0 | 0 | 0 |

*No convulsions observed among cattle fed at the 1500 mcg. level; however, 2 heifers showed staggering gait which were probably closely associated with convulsions.

In these four experiments in which 115 feeder calves were fed carotene levels ranging from about 800 to 1800 micrograms per 100 pounds live weight daily, 99 were completely night blind, 15 showed 2 degrees of night blindness, and one showed 1 degree at the close of the test periods. Of 23 head fed levels of 2000 to 2500 micrograms, 4 were completely night blind, 16 showed 2 degrees, and 3 showed 1 degree. Of 8 steers fed 3000 micrograms, one was completely night blind, 3 showed 2 degrees, 3 showed 1 degree and one was normal. Of 8 steers fed 5000 micrograms, 5 were normal and 3 showed 1 degree of night blindness.

Convulsions as observed were recorded, Table 8, perhaps because of their alarming nature rather than because of their being a common manifestation of vitamin A deficiency. It is also to be understood that the animals were not under continuous observation so that convulsions could have occurred that were not observed. No convulsions were observed in Experiment 4, but in Experiment 5, 1938-39, the number of convulsions was correlated with the carotene level in that 23 convulsions were noted for 6 steers in Group 1 on 800 micrograms, 5 for 5 steers in Group 2 on 1000 micrograms, 1 each for Groups 3 and 4 fed 1250 and 1500 micrograms and none for Group 5 fed 2000 micrograms. In Ex-

periment 6, 1939-40, in which 3 groups of heifer calves were supplied approximate carotene levels of 800, 1000, and 1500 micrograms for 100 days following depletion, and the fourth group was fed 1000 micrograms from the outset 3 convulsions were observed on the 800 microgram level and 2 were observed for each of the groups fed 1000 micrograms. No convulsions were observed on the 1500 microgram level but 2 of the heifers were observed for staggering gait and this condition according to observation is closely associated with convulsions. In Experiment 7, 1940-41, 2 convulsions were observed for Group 1 on 1250 micrograms and 1 for Group 2 on 1500 micrograms. One other steer in Group 2 showed staggering gait at the close of the 140-day test period.

On levels of 800, 1000 and 1250 micrograms of carotene clinical symptoms of vitamin A deficiency were much more evident than upon the higher levels; however, there were differences in the symptoms and in their intensity between years for the same levels. In Experiments 4 and 5 the steers fed the 800 and 1000 microgram levels were more difficult to keep on feed than those fed the three higher levels. Fullness at the hocks was observed sooner or later among almost 100 per cent of the steers on all of the levels. As compared to cattle which had received an abundance of carotene all groups showed more suffering from summer heat and more of the condition of watering at the eyes. In Experiment 6, despite the low levels of carotene used the groups of heifers were practically normal in appearance although a few individuals showed affected condition. These heifers, however, were kept on the test level for only 100 days and were marketed June 1 or before hot weather set in. In Experiments 6 and 7 the fullness at the hocks as noted in Experiments 4 and 5 did not occur. The steers used in Experiment 7 also showed few outward manifestations of vitamin A deficiency, except as previously noted for the 1250 and 1500 microgram levels. All of the cattle used in these four experiments fattened to a satisfactory finish and were sold for slaughter without rejection. However, on the basis of the observed symptoms of vitamin A deficiency, even 1500 micrograms of carotene per 100 pounds live weight daily did not maintain an entirely desirable degree of health. Of 33 animals involved in the study of this level, two were observed to show convulsions and 3 others were observed to show staggering gait and there was other evidence of continued depletion on this level in the 140-day period of feeding.

The trend of depletion as evidenced by night blindness for the several carotene levels used in Experiments 4, 5, 6 and 7 is shown in Figures 11, 12, 13 and 14. The curves representing the degrees of night blindness observed for the several carotene levels show that 1500 micrograms of carotene per 100 pounds live weight daily or less are inadequate to control night blindness, that various degrees of night blindness persist in the range from 1500 to 2500 micrograms and that levels of 2500 to 5000 micrograms may control night blindness quite well in the periods of time in which the levels were supplied.

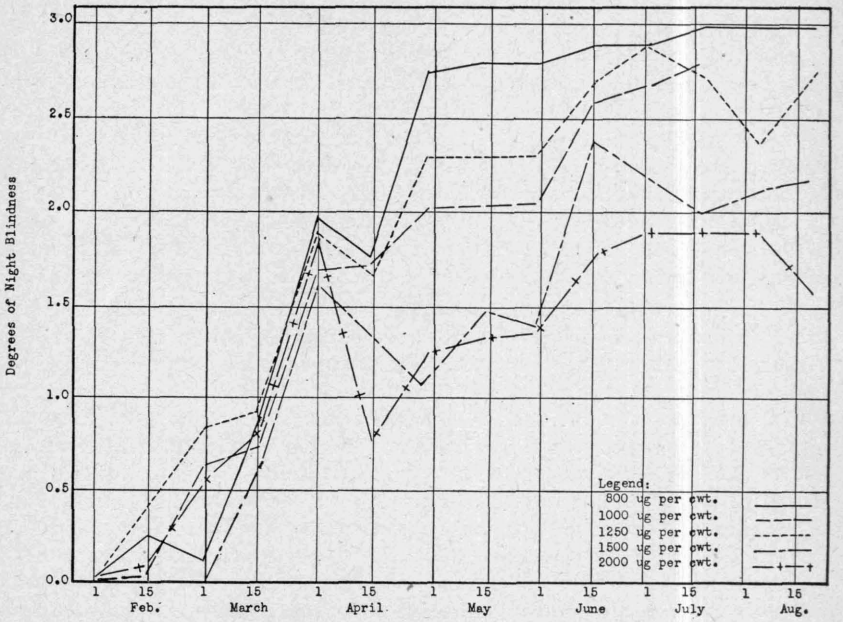



**Figure 11. Experiment 4, 1937-38. Response of night blindness of steers to carotene level. The animals were depleted and started on their carotene levels on April 1. The curves represent the average for all animals fed a given level. ug=microgram.**

The separate figures and individual curves representing the different groups show other interesting phenomena. It was noted in Experiment 3, and in Experiment 2 that there was a definite improvement in night blindness when low carotene levels were succeeded by higher carotene levels. Except in the case of severely depleted animals the effect is almost immediate improvement in degree of night blindness as noted in Experiments 4 and 5, Figures 11 and 12. There was a decrease in night blindness on each of the carotene levels for the first two weeks immediately after the carotene feeding began on April 1st in Experiment 4, and similar improvement resulted from the three higher levels used in Experiment 5. These decreases in degree of night blindness would have been misleading had the experiments been closed at the time, for there was an increase in night blindness upon all levels with the continuation of the experiments.

Figure 14, Experiment 7, 1940-41, shows that on March 6th tankage was removed from the ration of the steers fed the 1500 microgram carotene level. This was done in an effort to determine whether the tankage used was exerting a destructive action upon the carotene supplied by the dehydrated alfalfa leaf meal. No improvement in night blindness occurred after the tankage was removed from the ration.

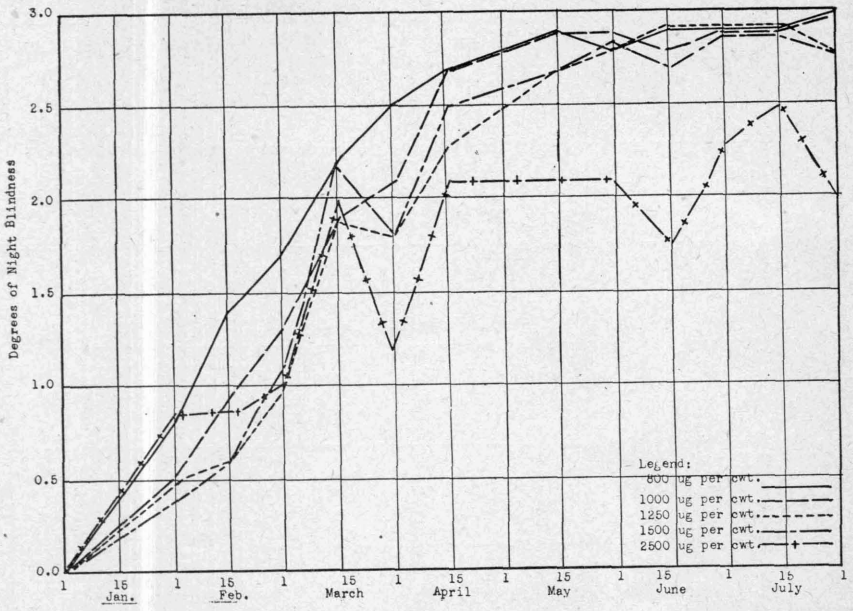



**Figure 12. Experiment 5, 1938-39. Response of night blindness of steers to carotene level. The animals were depleted and started on their carotene level on March 15. The curves represent the average for all animals fed a given level. ug=microgram.**

Other workers report that they have controlled night blindness with smaller amounts of carotene than was required in these Texas tests. Guilbert and Hart (10) in a study of the minimum carotene requirement by the curative method in which recovery experiments were started when the animals exhibited complete blindness in semidarkness and in which the intake of alfalfa supplement for each animal was repeatedly increased and decreased until night blindness and other symptoms disappeared or reappeared reported that the minimum requirement for beef cattle ranges from 26 to 33 micrograms per kilogram which is equivalent to 1182 to 1500 micrograms per 100 pounds live weight daily. In continuing the study of minimum carotene requirements these California workers (21) reported that the minimum requirement for mammals is in the order of 20 to 30 micrograms of carotene per kilogram body weight. The minimum requirements as determined by these investigators were defined as the lowest level per unit of body weight that prevented any detectable degree of night blindness under standard light conditions.

Ward, Bechdel, and Guerrant (22) reported that the minimum carotene requirement, an intake sufficient to maintain growth and to prevent the usual symptoms of vitamin A deficiency, of growing Holstein calves was 11 micrograms of carotene from a carotene concentrate per pound of body weight per day. It appeared that Guernsey calves required a slightly higher level. It also appeared that the intake should be considerably

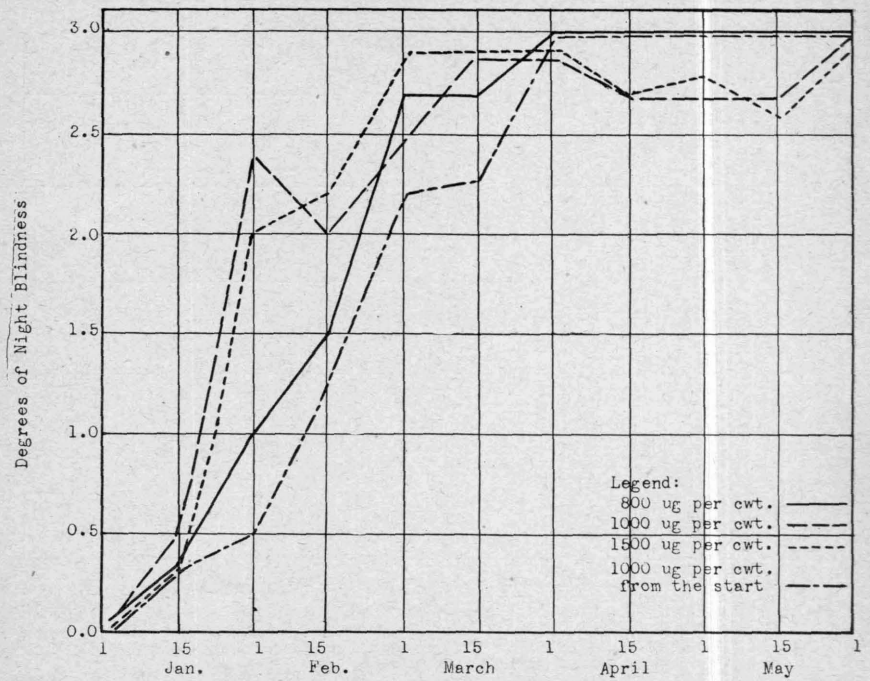



**Figure 13. Experiment 6, 1939-40. Response of night blindness of heifers to carotene level. The animals were depleted and started on their carotene level on February 15. The curves represent the average for all animals fed a given level. ug=microgram.**

above 11 micrograms, although larger amounts did not result in any marked improvement in rate of growth. Larger amounts of carotene were also required when the carotene was supplied by such feeds as alfalfa or timothy hay and silage feeds.

In a more recent report from the Pennslyvania Station by Keener, Bechdel, et al (15) it is stated that the minimum carotene requirement of dairy calves maintained at an environmental temperature of 50° to 70° F. was found to be approximately 12 micrograms per pound of body weight per day, but during severe winter weather calves receiving 20 to 23 micrograms of carotene per pound of body weight per day were observed to show deficiency symptoms. The authors state that the minimum carotene requirement for growth and well-being of dairy calves appears to depend upon environmental temperature.

There are points of similarity between the California and Pennsylvania results and our Experiment 2, involving yearling steers, in which some improvement in night vision resulted from the supply of a level of 1000 micrograms of carotene following the appearance of complete night blindness and the supply of an initial level of about 375 micrograms of carotene. Temporary decrease in night blindness was also noted in Ex-

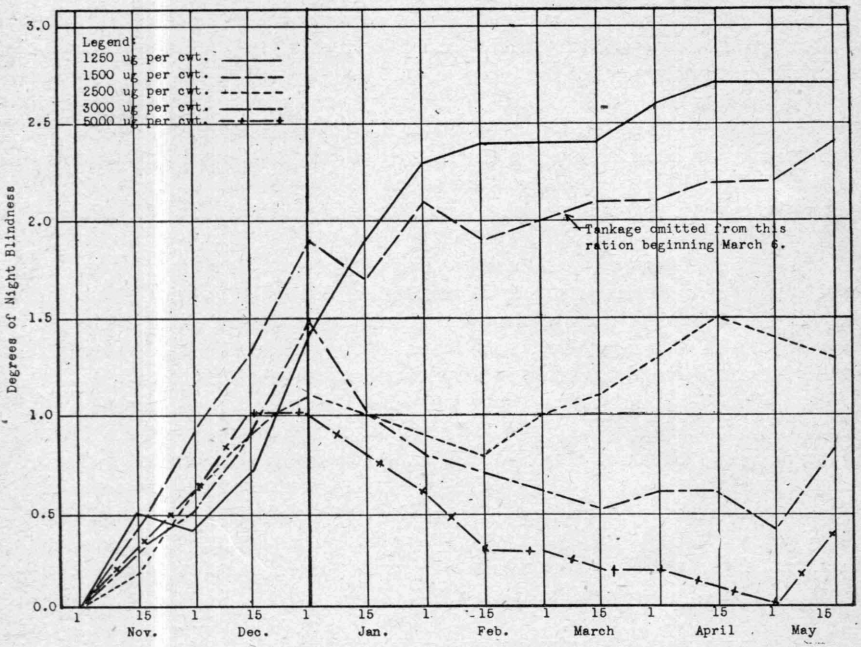



**Figure 14. Experiment 7, 1940-41. Response of night blindness of steers to carotene level. The animals were depleted and started on their carotene levels on January 1. The curves represent the average for all animals fed a given level. ug=microgram.**

periment 3 in changing from 750 to 1350 microgram carotene level. In Experiments 4 and 5 there was an almost immediate decrease in night blindness when carotene levels of 800 to 2500 micrograms were first supplied after the steers had become depleted but night blindness either increased or remained at about the same degree when these same levels were continued.

The method of feeding a ration high in concentrates during the period of supplying the carotene levels may partially explain the persistence of night blindness on the carotene levels used in Experiments 4, 5, 6 and 7, the results of which are at particular variance with the California and Pennsylvania results. The tendency toward increased manifestation of vitamin A deficiency on fattening rations was perhaps shown negatively by the steers in Experiment 3, which were fed the 450 microgram carotene level until death. These steers when reaching advanced depletion declined in appetite and lost weight. Of the 5 steers involved all showed similar marked decline in appetite the first year and 2 died. The other 3 partially recovered appetite, made gain for approximately one year, again failed in appetite, and in this decline 2 more died. The other steer again recovered and at the time of his fourth marked decline in appetite was sacrificed, because of urethral occlusion caused by uri-

nary calculi, after 993 days on the 450 microgram level. Hart and Guilbert (23) suggested a difference in the intensity of manifestations of vitamin A deficiency between cattle on low and on high energy intake in their discussion of vitamin A deficiency as related to reproduction in range cattle. While the evidence is not complete, difference in energy intake may be responsible for the fact that the California and Pennsylvania Stations were able to control night blindness with a level of carotene upon which cattle became completely night blind in Experiments 4, 5, 6 and 7.

The effect of low temperature in increasing the minimum carotene requirement as reported by the Pennsylvania Station (15) is of interest for in the main our results show that symptoms of vitamin A deficiency were intensified when the cattle were entirely exposed and when the daily maximum temperatures were within the range of 90 to 105 degrees Fahrenheit. Suffering from cold was also observed among severely depleted steers in Experiment 2. These observations were made during a period of 8 days at the Spur Station when the weather was cloudy and there was some rain and the minimum temperature ranged from 33 to 43 degrees Fahrenheit. It is logical to assume that suffering from vitamin A deficiency may be intensified by exposure to either high or low temperatures since animals severely depleted of vitamin A reserves are in a weakened condition.

## EFFECT OF QUANTITY OF CAROTENE UPON GAIN AND FEED CONSUMPTION OF FATTENING CATTLE

While the first three experiments showed that feeder cattle can be fattened on rations which are too low in carotene to sustain normal night

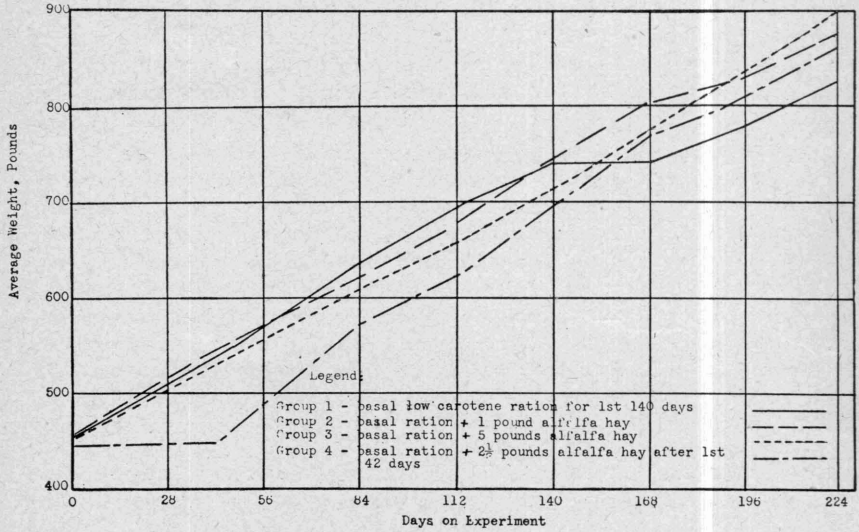



**Figure 15. Experiment 1, 1934-35. Weights of steers fed basal low carotene ration with various amounts of alfalfa hay.**

vision and health, or life if continued for long periods, the procedures were irregular and only the data from the last four experiments are used in evaluating the effect of quantity of carotene upon gain and feed consumption. However, the weight gains of the steer calves used in Experiment 1, 1934-35, are shown (see Figure 15) to illustrate the decline in gain or loss of weight which results from severe depletion of body reserves of vitamin A.

The lack of gain for Group 1, Experiment 1, fed the basal low carotene ration and the continuation of gain for Group 2 fed the basal ration plus 1 pound of alfalfa hay from the 140th to the 168th day on experiment is noticeable. It was during this period and in the following 28-day period that curative treatments for vitamin A deficiency were employed for Group 1. The treatments used resulted in a resumption of gain but not at a sufficient rate for Group 1 to equal the final weights of the groups which had been protected from vitamin A deficiency. Up to the point of "breaking" from vitamin A deficiency, which was 140 days, Group 1 had made as much gain and had eaten as much feed as the other groups. Figure 16 shows 5 of the steers from each of Groups 1 and 2 after 140 days on experiment. The difference in appearance of the two groups is typical of depleted and non-depleted steers in the feedlot.

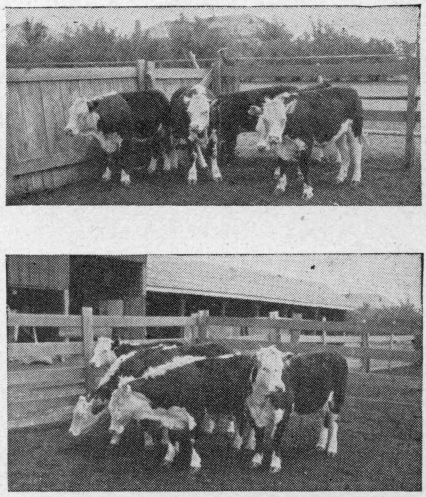


**Figure 16. Experiment 1, 1934-35. Upper—Group 1 steers fed basal low carotene ration after 140 days; Lower—Group 2 steers fed basal ration plus 1 pound good quality alfalfa hay after 140 days. At this time Group 1 steers were completely night blind, were sluggish, were declining in appetite and had ceased to gain while Group 2 steers were not night blind, were alert, had good appetite and were continuing to make normal rate of gain.**

Table 9 shows the average carotene levels, initial and final weights, rations consumed, and weight gains during the periods of fattening in Experiments 4, 5, 6 and 7. The digestible protein content and the therms of energy in the rations are also presented.

The actual carotene level as shown in Table 9 included the total quantity supplied in both alfalfa and grain. The carotene content of the grain was low, ranging from 0.18 to 0.69 part per million, but accounted for about 150 micrograms per 100 pounds live weight daily in Experiment 4 and 350 micrograms in Experiment 7. The fattening period was 100 days for the heifer calves used in Experiment 6 and 140 days for the steer calves used in

**Table 9. Average weights, gains, and rations consumed per head for fattening periods, Experiments 4, 5, 6, and 7**

| Carotene Level | | Weights in Pounds | | | Ration Pounds per Head | | | | | | | | Pounds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | Actual | Initial | Final | Carcass | 60% Prot. Tank. | CS Meal | Thr.Gr. Sorg. Grain | CS Hulls | Alf. Leaf Meal | Per Cwt. Daily | Dig. Prot. | P.V. Therms. | Daily Gain | Feedlot Gain |
| Steers, 1937-38, Experiment 4, 140 days | | | | | | | | | | | | | | |
| 800 | 935 | 725 | 949 | 571 | .65 | 3.25 | 4.90 | 13.0 | .55* | 2.67 | 1.98 | 9.49 | 1.60 | 224 |
| 1000 | 1143 | 734 | 938 | 565 | .66 | 3.29 | 4.97 | 13.18 | .69* | 2.73 | 2.03 | 9.67 | 1.46 | 204 |
| 1250 | 1410 | 708 | 946 | 559 | .69 | 3.42 | 5.14 | 13.69 | .84* | 2.88 | 2.11 | 10.06 | 1.70 | 239 |
| 1500 | 1662 | 703 | 974 | 582 | .69 | 3.42 | 5.19 | 13.64 | 1.01* | 2.85 | 2.14 | 10.16 | 1.94 | 271 |
| 2000 | 2196 | 719 | 963 | 582 | .68 | 3.40 | 5.15 | 13.57 | 1.37* | 2.87 | 2.16 | 10.23 | 1.74 | 244 |
| Steers, 1938-39, Experiment 5, 140 days | | | | | | | | | | | | | | |
| 800 | 836 | 698 | 900 | 539 | .59 | 2.94 | 4.83 | 11.23 | .19 | 2.48 | 1.79 | 8.79 | 1.44 | 203 |
| 1000 | 1034 | 700 | 941 | 559 | .64 | 3.21 | 5.33 | 12.20 | .26 | 2.64 | 1.96 | 9.66 | 1.72 | 241 |
| 1250 | 1286 | 695 | 943 | 564 | .69 | 3.44 | 5.80 | 13.02 | .30 | 2.84 | 2.10 | 10.42 | 1.77 | 248 |
| 1500 | 1508 | 694 | 947 | 572 | .67 | 3.34 | 5.59 | 12.66 | .36 | 2.76 | 2.06 | 10.13 | 1.81 | 253 |
| 2500 | 2485 | 700 | 950 | 578 | .64 | 3.22 | 5.37 | 12 21 | .60 | 2.67 | 2.04 | 9.86 | 1.79 | 250 |
| Heifers, 1939-40†, Experiment 6, 100 days | | | | | | | | | | | | | | |
| 800 | 791 | 571 | 758 | 436 | .52 | 2.61 | 7.72 | 6.19 | .065 | 2.58 | 1.78 | 9.41 | 1.87 | 187 |
| 1000 | 993 | 578 | 746 | 426 | .49 | 2.46 | 7.28 | 5.85 | .083 | 2.44 | 1.68 | 8.89 | 1.80 | 180 |
| 1500 | 1481 | 570 | 754 | 432 | .51 | 2.57 | 7.62 | 6.11 | .121 | 2.56 | 1.76 | 9.30 | 1.84 | 184 |
| 1000‡ | 1015 | 579 | 752 | 433 | .52 | 2.62 | 7.75 | 6.22 | .085 | 2.58 | 1.79 | 9.46 | 1.87 | 187 |
| Steers, 1940-41†, Experiment 7, 140 days | | | | | | | | | | | | | | |
| 1250 | 1599 | 484 | 748 | 431 | .54 | 2.72 | 7.05 | 7.80 | .11 | 2.96 | 1.80 | 9.31 | 1.89 | 264 |
| 1500 | 1837 | 487 | 756 | 444 | .23 | 2.93 | 6.94 | 7.74 | .13 | 2.89 | 1.73 | 9.18 | 1.92 | 269 |
| 2500 | 2830 | 490 | 760 | 441 | .56 | 2.78 | 7.20 | 7.98 | .22 | 3.00 | 1.86 | 9.57 | 1.93 | 270 |
| 3000 | 3350 | 485 | 767 | 444 | .56 | 2.79 | 7.25 | 8.01 | .26 | 3.01 | 1.86 | 9.64 | 2.01 | 282 |
| 5000 | 5328 | 494 | 768 | 439 | .55 | 2.73 | 7.08 | 7 83 | .44 | 2.95 | 1.85 | 9.51 | 1.96 | 274 |

*Ground alfalfa hay.
†Ground milo heads used.
‡947 mcg. per cwt. during depletion period

Experiments 4, 5, and 7. In each experiment the fattening or test period began with the close of the depletion period, although one group of heifers used in Experiment 6 received 1000 micrograms of carotene in alfalfa meal from the start of the depletion period. The average final weights were secured at the feedlot and the carcass weights were the average weights of the warm carcasses.

In Experiment 4, 1937-38, there was a general tendency for the steers fed the higher levels of carotene to consume greater amounts of feed, but the mean differences between levels were not great enough to be significant. In Experiment 5, 1938-39, the feed consumption was relatively low for the 800 microgram level; however, the average feed consumption for all levels was slightly lower than in Experiment 4. Ground alfalfa hay was used as the source of carotene in 1937-38 and dehydrated alfalfa leaf meal was used in 1938-39. The former was slightly unpalatable but not to such degree as to materially affect feed consumption. The latter was in instances obviously unpalatable and in the case of the steers receiving the 1500 and 2500 microgram levels feed consumption seemed to be reduced because of the amounts of alfalfa leaf meal necessarily fed. In the same year the 800 and 1000 microgram levels did not maintain normal well-being and less feed was consumed as a consequence.

In Experiment 6, 1939-40, and Experiment 7, 1940-41, there was little difference in feed consumption between carotene levels. In these experiments the cattle not only showed less outward evidence of depletion than formerly, but dehydrated alfalfa leaf meal, high in carotene, was used so that only small amounts were needed to supply the respective levels of carotene. The heifers used in Experiment 6 consumed appreciably less feed per 100 pounds live weight than the steers used in the other experiments; however, the heifers fattened more quickly and were fed a more concentrated ration from the outset of the depletion period. The steers used in Experiment 7 consumed comparatively large amounts of feed per 100 pounds because of their light weight and perhaps because of the adequacy of their carotene levels, 1599 micrograms being the lowest level that was supplied.

The differences noted in productive energy and digestible protein between groups in the same experiment resulted from differences in feed consumption since the feeds were given as a standard mixture. The average rations supplied adequate protein but were slightly short in productive energy as compared to feeding standards for quick fattening (24). The efficiency of feed utilization was not consistent with the increase in carotene level in the four experiments. The 800 microgram carotene level was the least efficient in gain only in Experiment 5. In this instance Group 1, fed the 800 microgram level, while consuming less feed made much lower gain than the other groups.

The total feedlot gains for the fattening periods while shown in Table 9 are also presented in Figures 17, 18, 19 and 20.

Statistical analysis of the gains for Experiment 4, 1937-38, showed that a mean difference between carotene levels of 42 pounds was required

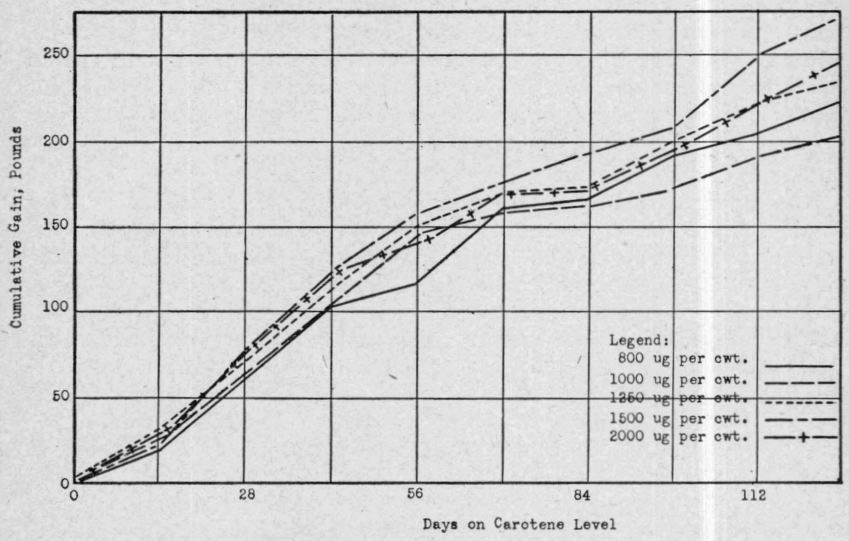



**Figure 17. Experiment 4, 1937-38. Gains of steers fed various carotene levels. The curves represent the average of all animals fed a given level. ug=micrograms.**

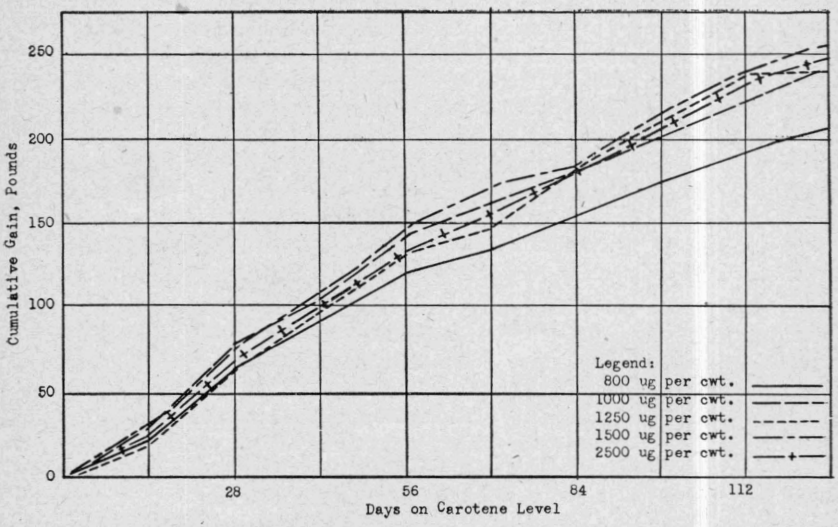



**Figure 18. Experiment 5, 1938-39. Gains of steers fed various carotene levels. The curves represent the average of all animals fed a given level. ug=micrograms.**

to be significant and 57 pounds to be highly significant; but only 31 pounds and 41 pounds, respectively, when the gains were corrected to a constant feed consumption. There appeared to be no consistent in-

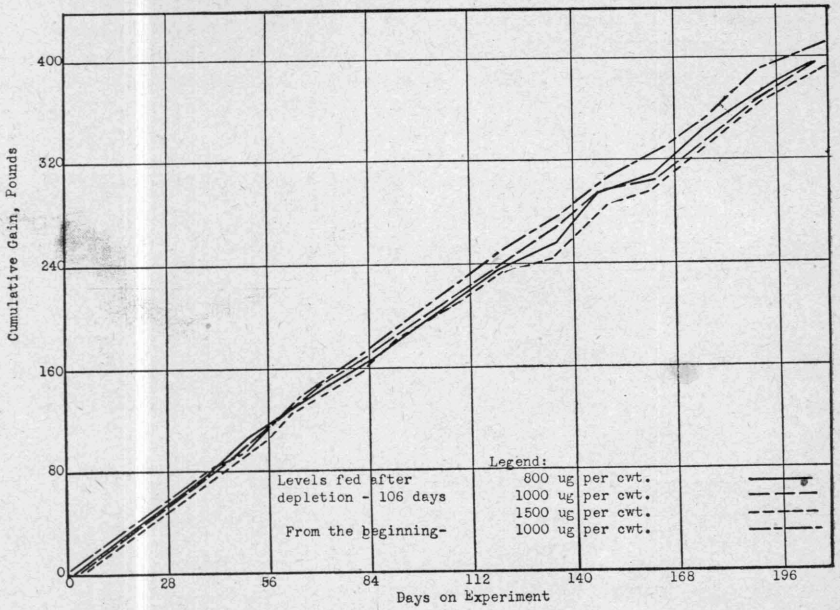



**Figure 19. Experiment 6, 1939-40. Gains of heifers fed various carotene levels. The curves represent the average of all animals fed a given level. ug=micrograms.**

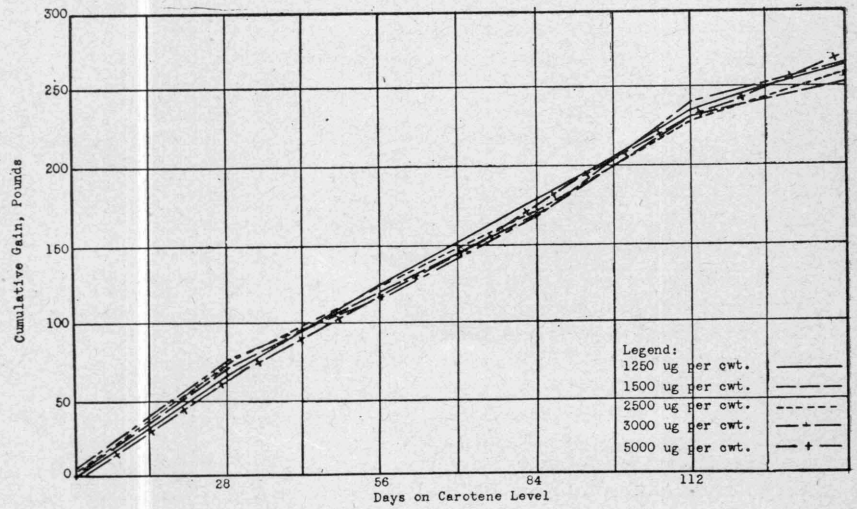



**Figure 20. Experiment 7, 1940-41. Gains of steers fed various carotene levels. The curves represent the average of all animals fed a given level. ug=micrograms.**

crease in gain induced by increased quantities of carotene although the mean square of the diets showed that significant differences in gain existed between Groups 2 and 4 on both corrected and uncorrected basis, between Groups 1 and 4 on uncorrected basis, and between Groups 3 and 4 on corrected basis. These results indicate that neither feed consumption nor carotene level was responsible for the differences in gain. Clinical observations, however, indicated that the carotene levels had a definite effect upon the general physical well-being of the animals.

Analysis of the data for Experiment 5, 1938-39, indicated that the mean difference in gain must be as large as 44 pounds to be significant and 59 pounds to be highly significant on the uncorrected basis and as large as 40 pounds and 54 pounds, respectively, on the corrected basis. Group 1 fed the 800 microgram level made significantly less gain than the groups fed the 1250, 1500 and 2500 microgram levels on the uncorrected basis, but when the gains were corrected for feed consumption all significant differences were eliminated.

In Experiment 6, 1939-40, the gains were so nearly the same between the carotene levels used that the experimental error in weighing could have been responsible for greater differences. There was likewise slight difference in gains between the carotene levels used in Experiment 7, 1940-41.

In each of the four experiments there was marked uniformity in finish and carcass grades for the several groups of cattle which were fed. The carcasses graded from Good to Choice and were noted for extremely white color of both external and internal fat.

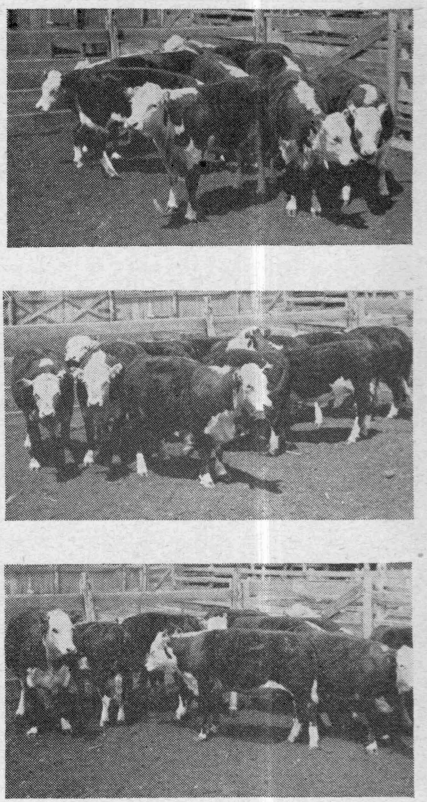


Figure 21. Fattened heifers used in Experiment 6, 1939-40. Fed for 206 days with 100-day test period of carotene levels. Note excellent finish of all lots even though carotene levels used did not prevent complete night blindness.

Upper Group 1—800 microgram level.

Center Group 2—1000 microgram level.

Lower Group 3—1500 microgram level.

Considering the general uniformity in the results in the four experiments in regard to gain and finish as indicated in Figure 21 it appears

that after the minimum amount of carotene needed to maintain the fattening animal in reasonably good health is supplied, larger amounts of carotene do not result in increased gains, increased finish, or higher carcass grades. Figure 22, showing Groups 1 and 5 from Experiment 7, illustrates the principal difference in outward appearance between the animals fed the higher and lower carotene levels in these four experiments.

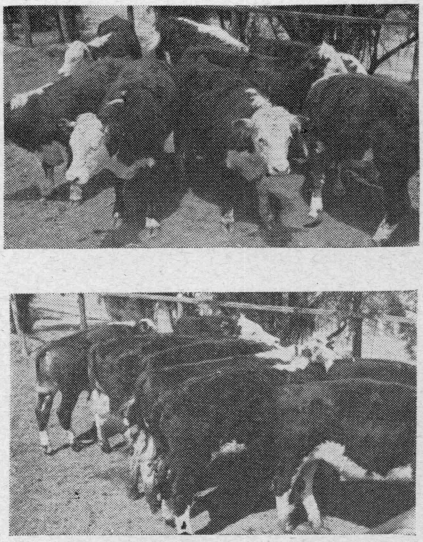


Figure 22. **Experiment 7, 1940-41. Upper—Group 1, fed 1250 microgram level Lower—Group 5, fed 5000 microgram level. Both groups are shown as fattened after having been fed 249 days, the last 140 days of which were spent upon the respective carotene levels. Note that Group 5 has the smoother, sleeker hair coat and that Group 1 lacks normal alertness.**

Feeder calves fed levels of 800 to 1250 micrograms of carotene, after depletion of body reserves of vitamin A as indicated by the occurrence of night blindness, have fattened satisfactorily and have made normal gain in periods of 100 to 140 days, but in most instances have shown lack of normal well-being. Those fed levels of 1500 micrograms have shown few symptoms of vitamin A deficiency other than complete night blindness, and night blindness has persisted upon levels of 2000 and 2500 micrograms. On levels of more than 2500 micrograms fed after depletion there was continued improvement in degree of night blindness. In considering the minimum carotene level that should be supplied to fattening cattle after depletion the crucial consideration is the well-being of the cattle. Night blindness, even of severe degree, can be tolerated as long as the cattle do not show other alarming symptoms, but when complete night blindnes occurs the feeder has no accurate means of determining degree of depletion. The carotene level should therefore be above 1500 micrograms and we suggest 2000 to 2500 micrograms as the minimum requirement under Texas conditions in order to provide a reasonable margin of safety. The feeder cannot afford to risk failure of appetite, undue suffering from heat, rough shaggy hair coat, or other factors involved in vitamin A deficiency that might affect the marketability of the cattle.

## RELATION OF QUANTITY OF CAROTENE TO CAROTENE AND VITAMIN A CONTENT OF LIVERS, BLOOD PLASMA, FAT AND LEAN TISSUE

Carotene and spectro vitamin A in the livers, blood plasma and fat of some of the cattle involved in these experiments were determined by spectrographic methods. The average carotene and spectro vitamin A

**Table 10. Carotene and spectro vitamin A content of livers from cattle fed various levels of carotene, codliver oil, and roughages**

| Experiment | Number animals | Days on depletion ration | Treatments and carotene intake mcg. per cwt. daily supplied after depletion | Days treated | Liver content ppm | |
|---|---|---|---|---|---|---|
| | | | | | Carotene | Spectro Vitam. A |
| 1 | 1 | 179 | No treatment. Died | --- | .2 | 2.1 |
| | 1 | 190 | 10 cc codliver oil | 34 | .4 | 1.3 |
| | 1 | 152 | 25 cc codliver oil | 72 | .3 | 7.9 |
| | 1 | 184 | 10 cc carotene in maize oil | 40 | 1.8 | 3.6 |
| | 2 | --- | 1 pound alfalfa hay | 224 | 1.3 | 6.4 |
| | 1 | --- | 2.5 pounds alfalfa hay | 182 | 3.7 | 13.5 |
| | 1 | --- | 5 pounds alfalfa hay | 224 | 2.5 | 17.0 |
| 1A* | 1 | --- | 8.7 pounds alfalfa hay | 168 | 2.1 | 5.1 |
| | 3 | --- | 12 pounds hegari fodder | 168 | 1.4 | 6.1 |
| | 4 | --- | 37 pounds sumac silage | 175 | 3.5 | 28.4 |
| 2 | 1 | 381 | No treatment | --- | .5 | 13.8 |
| | 4 | 205 | 549 | 166 | .5 | 4.6 |
| | 4 | 181 | 386 for 21 days, 1033 for 159 days | 180 | .6 | 4.1 |
| | 4 | 226 | 800 | 142 | .7 | 4.7 |
| | 4 | 154 | 282 for 30 days, 1751 for 181 days | 211 | .8 | 5.1 |
| | 4 | 246 | 2364 | 120 | 1.2 | 6.8 |
| 3 | 1 | 115 | 450—Died | 485 | -- | 1.6 |
| | 1 | 108 | 450—Died | 472 | -- | 2.1 |
| | 1 | 101 | 450—Died | 145 | -- | 4.5 |
| 6 | 5 | 112 | 791 | 100 | .5 | 1.8 |
| 5 | 5 | 105 | 836 | 140 | .6 | 1.9 |
| 4 | 5 | 133 | 935 | 140 | .7 | 1.7 |
| 6 | 4 | --- | 981 | 212 | .6 | 1.8 |
| 6 | 5 | 112 | 993 | 100 | .5 | 1.6 |
| 5 | 5 | 105 | 1286 | 140 | .7 | 1.6 |
| 4 | 5 | 133 | 1410 | 140 | .7 | 2.0 |
| 6 | 5 | 112 | 1481 | 100 | .7 | 1.7 |
| 7 | 5 | 118 | 1837 | 140 | .59 | 1.8 |
| 4 | 5 | 133 | 2196 | 140 | 1.2 | 3.2 |
| 5 | 5 | 105 | 2485 | 140 | 1.6 | 2.7 |
| 7 | 5 | 118 | 2830 | 140 | .9 | 2.4 |
| 7 | 5 | 118 | 3350 | 140 | 1.2 | 2.7 |
| 7 | 4 | 118 | 5328 | 140 | 1.37 | 4.7 |

*Steers from feeding trials conducted at Substation No. 9, Balmorhea, Texas, and from Substation No. 7, Spur, Texas, not in Vitamin A experiments and fed representative West Texas fattening rations.

content of the liver samples obtained in the several experiments are shown in Table 10. The carotene intakes shown in this table include the carotene supplied by both alfalfa and grain.

### Carotene and Vitamin A Content of Livers

The data obtained largely from single steers in Experiments 1, 1A, 2 and 3 may be mentioned. Of 4 steers from Experiments 1 and 3, which died from vitamin A deficiency, the average spectro vitamin content of livers was no lower than of steers fed carotene levels ranging from about 800 to 1800 micrograms in the last four experiments. The carotene and spectro vitamin A values of liver from steers fed daily allowances of 1, 2.5 and 5 pounds of alfalfa hay for 6 to 7 months in Experiment 1 and allowances of 8.7 pounds alfalfa hay, 12 pounds hegari fodder, and 37 pounds sumac silage for about 6 months in Experiment 1A, none of which showed outward evidence of depletion, are of interest when compared to the values shown by the variously depleted animals used in the later experiments. It is noted that the above values were equal to or higher in each instance than the average values found for steers receiving a carotene level of more than 5000 micrograms in Experiment 7. One steer in Experiment 2 which remained on the depletion ration for 381 days without becoming completely night blind but which had other symptoms of severe deficiency showed low carotene but a higher spectro vitamin A content of liver than the others. The record of this steer suggests differences between individuals in the utilization of carotene or of vitamin A for a given function. Of the other steers in Experiment 2 which had been variously depleted prior to the supply of the carotene levels there was a slight increase in carotene and spectro vitamin A with the increase of carotene level.

For Experiments 4, 5, 6 and 7 the carotene levels supplied are arranged in ascending order in Table 10. Storage of spectro vitamin A, as was expected from the carotene levels fed, was low in all cases. The carotene and spectro vitamin content of the livers increased in most instances, when the quantity of carotene fed was increased. There was little difference in the carotene and spectro vitamin A concentration in the livers on levels from 800 to 2000 micrograms. Above the 2000 microgram level the average values were higher.

In Experiment 7 there was a very regular increase in both carotene and spectro vitamin A on the carotene levels supplied by both alfalfa and grain ranging from 1837 to 5328 micrograms. The individual determinations, however, showed considerable variation as illustrated in Table 11. The individual variation upon the same level together with the general trend toward an increase in carotene and spectro vitamin A with increases in the supply of carotene indicate that it may be possible to determine from liver analysis whether an animal was suffering from vitamin A deficiency but that it is not possible to draw a sharp line of distinction between individuals on levels where they may or may not be affected.

**Table 11. Carotene and spectro vitamin A content of cattle livers (Expt. 7)**

| Steer No. | Carotene micrograms per cwt. daily, average | Liver content, ppm | |
|---|---|---|---|
| | | Pure Carotene | Spectro Vitamin A |
| 8 | 1837 | .84 | 1.9 |
| 35 | | .71 | 1.6 |
| 15 | | .54 | 2.1 |
| 48 | | .47 | 1.6 |
| 34 | | .40 | 1.8 |
| | Average | .59 | 1.8 |
| 21 | 2830 | 1.09 | 2.5 |
| 6 | | 1.08 | 2.8 |
| 37 | | .87 | 2.1 |
| 3 | | .80 | 2.0 |
| 7 | | .69 | 2.5 |
| | Average | .91 | 2.4 |
| 18 | 3350 | 1.85 | 2.5 |
| 24 | | 1.11 | 3.4 |
| 2 | | 1.11 | 3.2 |
| 11 | | 1.09 | 2.5 |
| 1 | | .93 | 1.8 |
| | Average | 1.22 | 2.7 |
| 28 | 5328 | 1.54 | 8.6 |
| 12 | | 1.33 | 2.4 |
| 29 | | 1.30 | 4.7 |
| 16 | | 1.30 | 3.2 |
| | Average | 1.37 | 4.7 |

## Carotene and Vitamin A Content of Blood Plasma

The carotene and spectro vitamin A in blood plasma were determined for part of the cattle used in Experiments 5, 6 and 7. Changes which took place in the carotene of the blood plasma are shown by the data obtained in Experiments 6 and 7, and are shown graphically in Figure 23. Four weeks after the heifer calves used in Experiment 6 were brought from the range and placed on the depletion ration samples of blood were drawn from 10 individuals selected from the group of 40 at random. The average carotene content of the plasma was 0.59 part per million. The animals were then divided into four groups of 10 each, one of which was fed a carotene level of 1000 micrograms per 100 pounds live weight daily from the outset while the other 30 were depleted of vitamin A. When the 30 had been depleted, samples of blood were drawn from 10 of them taken at random, and also from the 10 which had been fed the 1000 microgram level. The plasma carotene in the 10 depleted animals had dropped to 0.16 part per million and in the 16 head fed the 1000 microgram level to 0.32 part per million. The 30 depleted animals, in 3 groups of 10 each, were then fed for 100 days on levels of 800, 1000, and 1500 micrograms and the other group was continued on the 1000 microgram level. Then blood samples were drawn from 5 head in each group. The carotene concentration had risen from

the depletion average of 0.16 part per million to 0.19, 0.21, and 0.34 part per million in the groups fed 800, 1000 and 1500 micrograms carotene levels respectively, but had dropped from 0.32 to 0.27 part per million in the group fed the 1000 microgram level from the start.

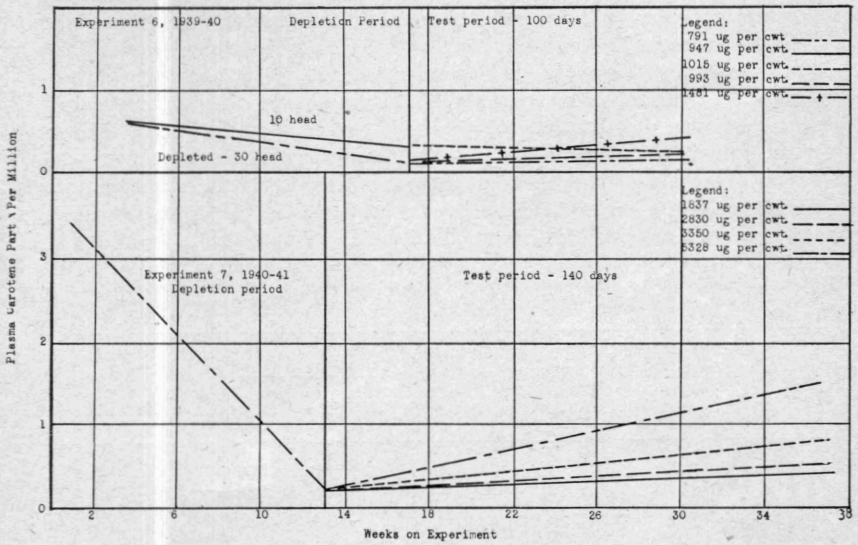



**Figure 23. Carotene concentration ppm of blood plasma from cattle fed various carotene levels. The curves represent the average of all animals fed a given level. ug=micrograms.**

In Experiment 7 the 10 initial blood samples, drawn at random, were secured within 5 days after the 50 feeder calves used were removed from the range. The average plasma carotene concentration was 3.42 part per million or 5.8 times as high as for the corresponding samples in Experiment 6. Since both groups of calves were approximately the same age and came from the same range upon which the rainfall had been practically equal in both years the three weeks' difference in time on the depletion ration prior to blood sampling may account for the above difference in initial carotene content of blood plasma. This difference at least indicates that the carotene content of the plasma drops rapidly when animals are changed from pasturage to rations practically free of carotene. When the calves became depleted of vitamin A blood samples were again taken at random from 10 head and the average plasma carotene content was 0.24 part per million. At this point the calves were started on the carotene levels, and at the close of the test samples were drawn from 5 calves fed on each of the four higher carotene levels. From the average of 0.24 part per million of plasma carotene at depletion the values rose to 0.47 on the 1500 microgram level, 0.56 on the 2500, 0.82 on the 3000, and 1.47 on the 5000 microgram level. Determinations of plasma

carotene from 2 animals on each of three levels were also secured in Experiment 5.

When the determinations at the end of the test period in Experiments 5, 6, and 7 are combined, Table 12, a general increase in plasma carotene is shown with the increase in carotene levels from about 800 to 5000 micrograms, but the spectro vitamin A content was not consistent with the increase of carotene level. In comparing the results of night blindness and plasma carotene determinations, complete night blindness prevailed at all levels up to 1837 micrograms and was not entirely corrected at levels of 2500 to 3000 micrograms. Animals fed the latter levels, however, had some degree of night vision and at about 5000 micrograms 5 steers out of 8 showed normal night vision and the remaining 3 showed only 1° of night blindness after 140 days. Convulsions were also observed on levels of about 1500 micrograms or less.

**Table 12. Carotene and spectro vitamin A content of blood plasma at close of test from cattle fed various levels of carotene. Experiments 5, 6, and 7**

| Experiment | Number of animals sampled | Test period days | Carotene micrograms per cwt. daily | Blood plasma, ppm | | Night Blindness |
|---|---|---|---|---|---|---|
| | | | | Carotene | Spectro Vitamin A | |
| 6, 1939-40 | 5 | 100 | 791 | .19 | -- | Complete night blindness prevailed |
| 5, 1938-39 | 2 | 140 | 836 | .22 | .25 | |
| 6, 1939-40 | 5 | 100 | 993 | .21 | -- | |
| 6, 1939-40 | 5 | 100 | 1015* | .27 | -- | |
| 5, 1938-39 | 2 | 140 | 1286 | .46 | .25 | |
| 6, 1939-40 | 5 | 100 | 1481 | .34 | -- | |
| 7, 1940-41 | 5 | 140 | 1837 | .47 | .38 | |
| 5, 1938-39 | 2 | 140 | 2485 | .66 | .18 | Some degree of night vision |
| 7, 1940-41 | 5 | 140 | 2830 | .56 | .34 | |
| 7, 1940-41 | 5 | 140 | 3350 | .82 | .32 | |
| 7, 1940-41 | 5 | 140 | 5328 | 1.47 | .41 | |

*Carotene intake 947 micrograms per cwt. daily during 106-day depletion period.

As previously noted, the heifers used in Experiment 6 at depletion, as indicated by the appearance of night blindness, showed 0.16 part per million of plasma carotene, while the steers in Experiment 7 showed a corresponding average value of 0.24. The average plasma carotene content of the 20 animals involved in the two experiments was 0.20 part per million; however, there was considerable individual variation in the data with a range of 0.10 to 0.35 part per million. The plasma carotene level at which night blindness might be expected to disappear after depletion and the supply of carotene was much less certain. At the close of the test period in Experiment 7, 6 steers showing more than 2° of night blindness averaged 0.54 part per million plasma carotene, one steer had slightly affected night vision at 1.77 part per million, and 3 which showed normal night vision averaged 1.08 part per million. Of 31 cattle involved in the three experiments and fed levels ranging from about 800 to 1800 micrograms of carotene for periods of 100 to 140 days after depletion, the average level of carotene in the plasma was .30 part per

million. The data from these experiments are hardly sufficient to establish definite levels at which night blindness may appear or disappear or at which health may be impaired; however, it is indicated that few symptoms of vitamin A deficiency other than night blindness are likely to be observed when the plasma carotene level exceeds .30 part per million.

Moore (12) found that an intake of about 16 micrograms of carotene per pound of body weight daily maintained plasma carotene at 0.2 microgram per milliliter, prevented night blindness and maintained a fair state of health in Holstein calves. He also noted that night blindness followed when the carotene value fell below about 0.13 microgram per milliliter. Davis and Madsen (25) stated that certain preliminary findings indicate that the critical level of carotene in the plasma is about 0.25 microgram per milliliter, and for vitamin A in the same sample 0.16 microgram per milliliter; and noted that at or above these levels animals do not usually show characteristic clinical symptoms of vitamin A deficiency. Keener et al (15) in a study of carotene in calf nutrition observed that when blood carotene fell below .0175 milligram per 100 milliliters of whole blood in Holstein calves, vitamin A deficiency symptoms were frequently found .

### Carotene and Vitamin A Content of Fat and Rib Cuts

Analyses were made of the rendered caul fat from 19 of the steers used in Experiment 7, 1940-41. The carotene and spectro vitamin A determinations were made by methods similar to those used for liver. The vitamin A potency was determined by feeding to rats, in comparison to carotene dissolved in oil. The average results for the four carotene levels which included samples from 19 fattened steers are shown in Table 13.

**Table 13. Carotene, spectro vitamin A, and vitamin A potency of caul fat of steers used in Experiment 7, 1940-41**

| Number of animals | Carotene level micrograms per cwt. daily | Part per million | | Vitamin A potency, I. U. per gram |
|---|---|---|---|---|
| | | Carotene | Spectro Vitamin A | |
| 5 | 1837 | .07 | .65 | .9 |
| 5 | 2830 | .12 | .75 | 1.2 |
| 5 | 3350 | .09 | .62 | .9 |
| 4 | 5328 | .11 | .86 | 1.1 |

The vitamin A content of the caul fat was very low, about 1 International Unit per gram. The animals receiving 5328 micrograms carotene per 100 pounds of live weight daily stored slightly more vitamin A in the caul fat than those fed 1837 micrograms, the difference being almost in the limit of error. The carotene content and spectro vitamin A content were only slightly greater in the caul fat from the animals receiving the higher level. Part of the spectro vitamin A probably consisted of compounds not vitamin A which absorb light in the same region

of the spectrum. This was shown by the low vitamin A potency of the fat when it was measured biologically.

Biological vitamin A assays of 12th rib cuts from the carcasses of the steers fed the 1250, 2500 and 5000 micrograms carotene levels supplied by alfalfa meal, or respective intakes of 1599, 2830 and 5328 micrograms of carotene, including carotene supplied by grain, in Experiment 7 were made. One composite sample of external fat and another of lean tissue were prepared from each of the respective carotene levels. The vitamin A content expressed as International Units per 100 grams of meat tissue for the respective samples were:

| Experiment | Carotene micrograms per cwt. daily | Vitamin A Content | |
|---|---|---|---|
| | | External fat | Lean tissue with intermuscular fat |
| 7 | 1599 | 33 | 14 |
| | 2830 | 33 | 16 |
| | 5328 | 96 | 33 |

It is noted that the values of the lean tissue with intermuscular fat are approximately 1-2 to 1-3 those of the external fat. The value of the external fat was low even from the steers on the 5000 microgram level as compared to values of 660 International Units per 100 grams of fatty tissue from rib cuts of cattle fattened on grass and 420 International Units in similar material from cattle fed grain and hay in dry lot as reported by Mohler (26).

## CONDITIONS UNDER WHICH VITAMIN A DEFICIENCY MAY OCCUR

When feeds low in carotene such as bleached hays or fodder, straw or cottonseed hulls form the roughage portion of the dry lot fattening ration feeder calves or yearlings may become depleted of body reserves of vitamin A before they can be fattened. The light feeder calves used in Experiments 8, 9, and 10, Table 1, were quickly depleted when fed cottonseed meal with sorghum roughage which had been more than a year in storage. In all of the experiments reported here feeder calves or yearlings became depleted and showed more or less advanced symptoms of vitamin A deficiency when cottonseed hulls were fed as the roughage with the sorghum grains and cottonseed meal. In a feeding trial at the U. S. Experiment Station, Big Spring, Texas (27) 27 out of 40 calves, average initial weight 450 pounds, on a fattening ration consisting of ground threshed milo, cottonseed meal and new crop sumac silage of apparent good quality became night blind after 130 days. Many other instances of vitamin A deficiency have been observed in dry lot fattening.

Hart and Guilbert (23) have reported that under dry range conditions forage becomes deficient in carotene and that vitamin A deficiency may develop on the range following long and severe drouth, which deficiency

resulted in reduced calf crop, difficulty in calving, and calves weak at birth.

There are several practical considerations concerning the occurrence of vitamin A deficiency in fattening cattle. The time required for feeder cattle to become depleted of body reserves of vitamin A when fed rations low in carotene in dry lot is affected by the amount and distribution of the rainfall during their development on the range. Range forages when green and growing are high in carotene and cattle grazing upon them accumulate reserves of vitamin A. The carotene content decreases as the plants grow older and the quantity is quite low in weathered grasses and forages so that the feeders may come off of the range with low reserves of vitamin A. In this case the time required for depletion in dry lot on rations low in carotene is less than for feeders removed from good range following a season of favorable rains. Light young feeder calves have less storage of vitamin A reserves than heavy calves or yearlings originating from the same range. According to the results of these experiments heavy feeder calves can be expected to become depleted on rations low in carotene within about 90 to 120 days in dry lot while light feeder calves may become depleted within 50 to 80 days depending in both instances upon the kind of range from which they were removed. Yearling feeders are less likely to become affected by vitamin A deficiency before they can be fattened in dry lot than calves for they can be fattened in less time and can be expected to have greater reserves of vitamin A than calves. Cattle remaining on the Texas ranges are not likely to suffer from vitamin A deficiency except during unusually long periods of drouth because of their ability to store reserves of vitamin A, the comparatively large amounts of grass eaten, the comparatively small amount of carotene necessary to prevent deficiency condition, and because, as shown in Table 14, numerous range plants contain fair amounts of carotene.

During severe drouth there is not only a lack of green feed but a shortage of total feed which results in a shortage of nutrients and minerals as well as of carotene. Under such extreme conditions the supplemental feeds should supply carotene in addition to other needed nutrients and necessary bulk. It is obvious that any range practice which conserves water for grass growth during the dry months is beneficial from the standpoint of carotene supply. Dickson (28) and associates have shown that contour listing increased the quantity of green grazing and hence increased the supply of carotene.

With reference to the crude carotene content of some Texas feeds, including grasses and other range plants shown in Table 14, a wide range in the carotene content of the same kind of feed, as for alfalfa, may be noted. Alfalfa hay showed 116 to 0.6 part per million carotene while dehydrated alfalfa leaf meal ranged from 304 to 53 parts per million. The alfalfa hay containing only 0.6 part of carotene per million had been stored for 3 years.

Marked variations in the carotene content of hays and feeds depending upon the method of curing and time in storage have been shown by

**Table 14. Crude carotene content of some Texas feeds, including grasses, and forage plants, dry basis***

| Description | Crude Carotene parts per million |
|---|---|
| Alfalfa hay | 116, 58, 51, 34, 27, 20, 14, 11, 9, 8, 6, 4, 3, 0.6 |
| Alfalfa leaf meal, dehydrated | 304, 283, 279, 269, 265, 254, 250, 222, 207, 186, 168, 147, 139, 112, 107, 97, 70, 66, 53 |
| Alfalfa stem meal | 65, 9 |
| Bermuda hay | 5, 2 |
| Bermuda grass, dormant | 2 |
| Bermuda grass, fresh green | 413, 361, 281, 187, 174 |
| Buffalo grass, dormant | 94, 34, 31, 26, 25, 22, 19, 15, 7, 4 |
| Buffalo grass, fresh green | 254, 226, 207, 179, 169, 167, 155, 146 |
| Cactus, spineless | 33 |
| Cactus, prickly pear | 6 |
| Corn shuck | .7 |
| Clover meal | 18 |
| Clover, bur, fresh green | 364 |
| Clover, sweet, fresh green | 418 |
| Dallis grass, dormant | 15 |
| Dallis grass, fresh green | 495, 372, 227 |
| Grama grass, hairy, dormant | 18, 8, 8 |
| Grama grass, hairy, fresh green | 122 |
| Guajillo leaves, fresh green | 105 |
| Johnson grass, fresh green | 366, 365 |
| Kafir silage | 35, 22, 18, 15, 9, 8, 5, 5, 4, 3, 3, 2 |
| Liveoak leaves, fresh green | 133, 55 |
| Mesquite leaves, fresh green | 44 |
| Milo fodder | 2 |
| Needle grass, dormant | 13, 9 |
| Peanut hay | 45, 39, 16 |
| Postoak leaves, fresh green | 114, 81 |
| Prairie hay, largely bluestem | 32, 19, 18, 18, 14, 11, 9, 8, 8, 3 |
| Rhodes grass hay | 2 |
| Rhodes grass, fresh green | 283 |
| Rescue grass, fresh green | 406 |
| Rye, Italian, fresh green | 373 |
| Sorghum hay or fodder, sumac | 4, 3, 2, 2, 2, 2, 1, 1, 0.8 |
| Sorghum silage, sumac | 51, 43, 33, 31, 30, 25, 20, 18, 15, 14, 5, 4, 2 |
| Sotol leaves, fresh green | 42 |
| Sotol bulb, fresh | 2 |
| Sudan grass hay | 9, 6, 4 |
| Cottonseed meal | .07 |
| Feterita, threshed grain | .3 |
| Hegari, threshed grain | .4 |
| Hegari grain screenings | .9 |
| Kafir, threshed grain | .4, 0.4, 0.3 |
| Milo heads ground | .69 |
| Milo threshed grain | .2 |

*As reported by Kemmerer et al. (30) and analyses by Division of Chemistry, T.A.E.S.

many research workers. Fraps and Treichler (29) reported that vitamin A content of feeds decreased in accordance wtih the length of time in storage and that alfalfa leaf meal lost 50 per cent and yellow corn 30 per cent of the vitamin A potency in 5 months under storage conditions. Yellow corn, when fresh, may contain about 5 units of vitamin A potency per gram. The ground milo heads used in the experiments contained at the most .69 part per million of carotene, ground threshed milo ranged from .2 to .4 part per million.

Sumac silage, as shown in Table 14, ranged from 51 to 2 parts per million of carotene on dry basis. Kafir silage showed a range of 35 to 2 parts per million of carotene. The higher values for both of the above silages were shown for the samples secured just after the trench silos

were opened in the fall. With the successive samples taken at 14-day intervals until the silos were emptied in early summer there was a steady decline in carotene value from start to close of the feeding period. There are some indications that the carotene when contained in small amount in hays and fodders may be utilized by fattening cattle to less extent than the carotene in alfalfa.

It is obvious from Table 14 that the quantity of a feed required to supply a given carotene level depends upon the carotene content of the feed. In Experiment 1, one pound of good quality alfalfa hay fed per head daily was sufficient to protect feeder steer calves from vitamin A deficiency for more than 224 days; however, the micrograms of carotene supplied in that instance was not known. In the later experiments levels of about 2500 micrograms of carotene prevented the manifestation of symptoms of vitamin A deficiency other than a degree of night blindness. Assuming a required level of 2500 micrograms per 100 pounds live weight daily for a 500 pound steer we find, since a pound contains 453.6 grams and one part per million equals one microgram per gram, that one pound of alfalfa hay containing 27.5 parts carotene per million would supply 12500 micrograms of carotene or 2500 micrograms per 100 pounds of steer. Should it be desired to supply an 800 pound steer 5000 micrograms of carotene per 100 pounds of live weight it would be necessary to feed about 3.2 pounds of alfalfa containing 27.5 parts of carotene per million.

As previously noted, light calves may be expected to show sign of depletion about 50 days after their removal from the range and placement in dry lot on rations low in carotene. It has also been noted that severe vitamin A deficiency condition should not be allowed to develop. Fortunately the onset of vitamin A deficiency condition can be easily recognized by observing the cattle after dark. Night blindness, practically always the first symptom, appears before the cattle suffer damage in regard to fattening. Even after the appearance of night blindness the deficiency can be corrected in fattening cattle by feeding good quality alfalfa, other green feeds, or high vitamin A potency cod liver oil. Only small amounts of alfalfa hay or other curatives are required to prevent this condition and response to treatments is usually rapid and easily recognized.

## SUMMARY AND CONCLUSIONS

Cattle fed rations very low in carotene in dry lot for a considerable length of time lose their reserves of vitamin A and will, if retained on such rations, die unless carotene or vitamin A is provided.

In seven experiments conducted from 1934 to 1941 with 310 feeder cattle ranging from 3 to 16 months of age at the time of being placed in the feedlot and fed rations low in carotene, the time required for depletion of body reserves of vitamin A, as indicated by night blindness, ranged from 45 to 268 days. Young animals became depleted in less time

than older animals. In drouthy years less time was required for depletion than in favorable years. Young animals have less storage of vitamin A than older ones and consequently exhaust their reserves more quickly, while animals which have had green forage high in carotene accumulate greater reserves than those which have had dry forage which is low in carotene.

Night blindness was practically always the first symptom of vitamin A deficiency that could be observed. Watering at the eyes, sluggishness, complete night blindness, nasal discharge, suffering from solar heat as characterized by panting and slobbering, convulsive seizures, body swellings, day blindness, loss of appetite, loss of weight and finally death were other progressive symptoms of vitamin A deficiency which were observed. At the point of visible body swellings the subcutaneous tissues were found to show an edematous infiltration. In cases of advanced vitamin A deficiency this condition led to the condemnation of the carcasses.

A carotene level of 450 micrograms was not sufficient to sustain life during extended periods of feeding. Steers supplied this level after depletion fattened but their carcasses showed a generalized edema sufficient to warrant their rejection as a food. Gains were continued until the animals showed marked symptoms of vitamin A deficiency and losses in weight did not occur until there were marked losses in appetite. These results show that carotene is not needed in the fattening ration for the production of gain as long as the body reserves of the animals meet their requirments for well-being. It is only when the body reserves of vitamin A become depleted that fattening cattle show symptoms of vitamin A deficiency.

Curative treatments for vitamin A deficiency consist in increasing the quantity of carotene in the ration through green growing feeds, legume hays of high quality such as alfalfa, or the supply of vitamin A by the administration of cod or other fish liver oils high in vitamin A. Green forage or hays, particularly alfalfa of pea green color, are excellent sources of carotene. In the usual periods of time required for fattening beef cattle the addition of 1 to 2 pounds of good quality alfalfa hay to the ration may usually be expected to prevent the occurrence of vitamin A deficiency. If the condition has been allowed to develop it can usually be remedied by feeding 2 to 4 pounds of good quality hay per head daily or by daily dosing with 50 to 100 cc of commercial grade cod liver oil, for a period of 2 to 3 weeks.

Carotene levels of about 1500 micrograms supplied by either alfalfa hay or dehydrated alfalfa leaf meal to fattening feeder calves were not sufficient to prevent the development of complete night blindness in test periods of 100 to 140 days after depletion. Of 115 head fed from about 800 to 1800 micrograms of carotene, 99 became completely night blind. Of 23 head fed 2000 to 2500 micrograms, 4 became completely night blind and the remainder were partially night blind. On 3000 micrograms fed after depletion the tendency was toward improvement in night vision.

In one test with 5000 micrograms of carotene 5 steers out of 8 regained normal night vision within 140 days. Carotene as high as 1250 micrograms permitted day blindness to develop and a few instances of staggering gait and convulsions were observed at the 1500 microgram level.

Quantities of 800 and 1000 micrograms of carotene fed per 100 pounds live weight daily or one pound of alfalfa hay did not induce significantly greater gain than was made by calves fed the unsupplemented depletion ration, but did delay the occurrence of night blindness. Carotene when supplied in larger amount than necessary to prevent severe depletion did not produce significant increase in gain.

There was practically no storage of carotene or spectro vitamin A in the livers of cattle fed up to 1800 micrograms carotene. Slight storage took place on 2500 and 3000 micrograms and while even more storage occurred on 5000 micrograms the amount was still very small.

The average carotene and spectro vitamin A content of rendered caul fat from cattle fed carotene up to 5000 micrograms was low. Composite samples of external fat and of lean tissue with intermuscular fat from rib cuts of steers fed about 1250, 2500 and 5000 micrograms carotene were likewise low in vitamin A in comparison to the values found in similar samples from steers fattened on grass. Lean tissue with intermuscular fat contained only 1-3 to 1-2 as much vitamin A as external fat. Higher vitamin A potency in the body fat resulted from increases in carotene level, but it is apparent that a relatively high carotene intake is necessary for an appreciable amount of storage.

There was a regular increase in blood plasma carotene on levels of intake ranging from about 800 to 5000 micrograms although the increments were small from about 800 to 1800. Plasma carotene apparently takes a sharp initial drop when cattle are first removed from pasturage and fed a ration low in carotene. With continued depletion the decline is apparently slow with night blindness appearing when the carotene drops to about .20 part per million of blood plasma.

The carotene requirement for fattening beef cattle is that quantity which will allow animals to maintain satisfactory physical condition during the fattening period involved. In these experiments 1500 micrograms per 100 pounds live weight daily allowed in most instances satisfactory feed consumption and gain but to allow a margin of safety a level of 2000 to 2500 micrograms is recommended.

Sorghum roughages, straws, and some other roughages and grains frequently do not contain enough carotene to prevent the occurrence of vitamin A deficiency in cattle fed for long periods in dry lot. Periodic checks for night blindness may be made after the first 50 days in the case of young feeder calves fed on rations low in carotene. If a vitamin A deficiency is then indicated, it can be remedied with alfalfa hay or green feeds. One to 2 pounds of good quality alfalfa hay per head daily included in an otherwise low carotene ration usually supplies a 500-pound feeder animal 2000 to 6000 micrograms carotene per 100 pounds live weight.

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