LEVELS OF VITAMIN A SUPPLEMENTATION OF A STEER-FATTENING RATION CONTAINING HIGH OR LOW LEVELS OF SILAGE

by

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INTRODUCTION

The problems involved in vitamin A nutrition of beef cattle at the present time may be resolved into three main principles. In the first place, it is recognized that not as much is known about vitamin A metabolism in the animal body, as compared with what is known about the B vitamins. For that reason, one should constantly be aware that the present methods of evaluating vitamin A requirements of beef cattle may not take into account other factors as yet unrecognized, and that one should expect constant changes in the stated requirements as more information is gathered through research and changes in feeding practices.

Secondly, cattle feeders and research workers do recognize that feeding practices have changed considerably over the past years, especially as regards the increasing use of high-concentrate fattening rations. Also, it is believed that owing to the stress of feed-lot conditions, the vitamin A requirements of beef cattle should be increased. The National Research Council's Subcommittee on Beef Cattle Nutrition took these factors into consideration when the nutrient requirements of beef cattle were revised in 1963.

Again, it is believed that the level of green roughage in feed-lot rations can be reduced to the minimum which would only support adequate rumen function, and that this minimum level can also be replaced with non-green roughage. This idea has received much support because synthetic vitamin A is now available on the market at a reasonable price and therefore the use of green roughage as a source of provitamin A may not be necessary.

The third major problem in vitamin A nutrition in recent years is the increasing awareness of the fact that certain factors in feeds may affect the optimum utilization of the vitamin. It has been amply demonstrated that high levels of nitrate in silage due to the application of high levels of nitrogen fertilizers can cause a depletion of blood and liver reserves of vitamin A. A few reports have also indicated that carotene in corn silage may not be utilized as efficiently as it is supposed.

In the face of these problems, it seems that in trying to determine the vitamin A requirements of feed-lot cattle some consideration should also be given to the use of experiments which would give information on the use of particular types of feedstuffs under more practical conditions. Ideally, this should involve studies with feedstuffs from different geographical locations where one has reason to believe that marked differences in the soil, climate and agricultural practices exist.

The present experiment was designed to get information on levels of vitamin A supplementation of steer fattening rations containing high and low levels of silage.

REVIEW OF LITERATURE

Historical

Vitamin A was placed in the lime-light of animal nutrition in 1913 when McCollum and Davis (1913) observed that growing rats on a purified experimental diet suddenly ceased to gain weight unless an ether-soluble substance in butter or egg-yolk was added. The authors went on to isolate the ether-soluble dietary essential and named it Fat-soluble A, (McCollum and Davis, 1915). Contem orary research by Osborne and Mendel (1915) confirmed these findings and also broadened the scope of investigations when it was observed that deficiency of fat-soluble A was associated with the incidence of bacterial infections and ocular lesions in experimental animals.

Osborne and Mendel (1917) reported incidence of 'phosphatic urinary calculi' in about 43 per cent of rats fed a diet deficient in Fat-soluble A. McCollum et al. (1921) also reported bone malformations or rickets in rats fed a diet which was deficient in Fat-soluble A. Steenbock (1921) also cured ocular lesions in dogs with fresh cabbage.

Earlier, the research of McCollum et al., (1917) and Osborne and Mendel (1919) had shown that green leafy vegetables as well as cereal and oil seeds, possessed some Fat-soluble A activity. It was further observed by McCollum et al. (1917) that the small cereal grains which contained more germ material in proportion to the endosperm, were more effective than the large cereal grains. Apparently, vitamin E rather than vitamin A was the principle involved.

Quantitative methods of estimating vitamin A activity of test materials were much improved when Carr and Price (1926) discovered the antimony trichloride reaction, although it awaited the later developments of more sensitive colorimeters and spectrophotometers to utilize the method to greater advantage.

Karrer et al. (1931) successfully elucidated the chemical structure of vitamin A which was followed six years later by the synthesis of the vitamin by Kuhn and Morris (1937).

Meanwhile experiments by Moore (1930, 1931, 1933) on the metabolic inter-relationship between vitamin A and carotene were providing useful information as well as techniques for vitamin A experiments. By supplementing the diets of vitamin A-depleted rats with either crystalline carotene or vegetables containing carotene, it was observed that small doses of carotene were utilized as efficiently as vitamin A. It was also found that the liver was the main site of storage of the vitamin in the body, and that the organ also contained unchanged carotene.

This latter observation led to the unfortunate conclusion that the liver was the site of conversion of carotene to vitamin A, an idea almost unquestionably held until other workers, including Mattson et al. (1947) and Wiese et al. (1947) proved that the wall of the small intestines was the main site of conversion. Glover et al. (1947) provided evidence on the mechanism of conversion of carotene to vitamin A, when they isolated vitamin A aldehyde from the intestinal wall after feeding carotene.

Some evidence as to the mode of absorption of vitamin A was suggested by the work of Gray et al. (1940) but it was Mahadevan and his colleagues (Mahadevan and Ganguly, 1961, and Mahadevan et al., 1963) who showed in detail that vitamin A in the ester form was de-esterified during absorption and then re-esterified after absorption, mainly as the palmitate ester.

From the brief sketch of the history of vitamin A it should be apparent that by the late 1930's much information had been secured on vitamin A nutrition by the use of the rat. The information collected was enough to form ground-work material for application to other species.

A symposium organized by the American Medical Association in 1939 fully recognized the therapeutic uses of vitamin A in the human (Clausen, 1939). Earlier, Guilbert and Hart (1934) had initiated vitamin A studies in farm animals, especially the bovine.

Studies in Vitamin A Nutrition as They Apply to Cattle

The main objective of the experiments by Guilbert and his associates (1934-1940) was to determine the level of vitamin A or carotene that would prevent the incidence of night-blindness in cattle. This required preliminary depletion of the test animal to the point where night-blindness ensued, and the feeding of vitamin A or carotene at graded levels to the animal in order to determine the minimum requirement of the vitamin.

By this method, Guilbert and Hart (1934) found that it required approximately 225 days to deplete well-pastured cattle, and that it required 29 mcg of carotene/kg of body weight to relieve the deficiency symptoms (Guilbert et al., 1935).

Additional tests on cattle, sheep, swine and horses by Guilbert et al., (1937, 1940) led to the conclusion that for the mammalian species, 25-30 mcg of carotene or 6-8 mcg of vitamin A per kilogram of body weight would prevent symptoms of vitamin A deficiency and permit excellent weight gains. In other words, the vitamin A requirements depended primarily on body weight.

There were two flaws in these experiments. Sometimes only small numbers of animals were used, even though this was largely compensated for by the long periods of study and the inclusion of animals from wide ranges of weight and age. Also the description "excellent gains" was a subjective appraisal and sometimes the weights were not reported.

Apparently the carotene and vitamin A requirements as published by the National Research Council (1958) were based primarily on the findings of Guilbert and his associates (Guilbert and Loosli, 1951).

Later workers who attempted to repeat these findings encountered disappointing inconsistencies. Boyer et al. (1942) working with three dairy breeds, Guernsey, Holstein, and Brown Swiss, noted that vitamin A levels of 6 mcg/kg body weight retarded growth rate; 12 mcg/kg was found to be borderline. Similarly, carotene intake at the rate of 60 mcg/kg body weight was insufficient in all the breeds even though the Holsteins required less than the Guernseys.

The breed differences in carotene requirements were also recognized by Ward et al. (1940) and Braun (1945); the latter worked with Jerseys, Holsteins and Herefords and the former with Guernseys and Holsteins.

At this point in vitamin A research, the emphasis was shifting to finding other indexes of vitamin A adequacy, principally, the relationship between vitamin A and carotene in the diet and the resulting levels in the liver or plasma, and possibly, how these values might influence the rate of growth. This was a different approach from that of Guilbert and associates (1934-1940) where the approach was of the nature of a clinical investigation. However, their unguarded conclusions on weight gains had aroused much doubt.

Braun (1945) did not find any relationship between the amount of carotenoids or vitamin A stored in the liver and the corresponding amounts in the plasma. However, it was observed that during rapid depletion of vitamin A or carotenoid stores of the liver, without simultaneous intake, there was a good relation between the vitamin A in the liver and in the blood.

Similarly, Frey et al. (1947) using diets containing six graded levels of vitamin A, concluded that there was a good relationship between the level of the vitamin in the diet and that in the liver, but the relationship was not by any means simple. Apparently, there was a threshold effect.

Thomas et al. (1952) concluded that plasma vitamin A was a misleading index. In experiments with calves, the authors had noted that with diets high in vitamin A, the plasma vitamin A definitely increased soon after the meal but afterwards it tended to fall to levels below the original. But these experiments, as admitted by the authors, were of short duration. However, Thomas and Moore (1952) concluded again that liver vitamin A was a better indicator of vitamin status than plasma vitamin A and that plasma carotenoids (as distinguished from beta-carotene) were a better indicator than plasma vitamin A when the animal was on a given constant intake of a diet containing carotene. But again, it was noted that animals which were truly deficient in vitamin A would show low levels of plasma vitamin A.

Parrish et al. (1948) examined the chemical methods of determining blood vitamin A and carotenoids which were prevalent at that time, but their results could not make any significant changes in the conclusions already reached.

Diven et al. (1960) by applying a rigorous mathematical treatment to the subject, concluded that there were positive correlations between all possible pairs of comparisons, but it was advised that the prediction equations were useful only where animals were on diets supplying critical levels of vitamin A, and where the constant and variable functions in the equation were clearly defined.

The review article by Ganguly (1960) and the experiment by Deshmukh et al. (1964) seem to shed some light on this peculiar behavior of vitamin A in the body. The findings are that vitamin A exists in the liver mainly as vitamin A ester conjugated to a lipo-protein complex. In the blood, it exists mainly as the alcohol form conjugated to the lipo-protein complex. Also, the vitamin A ester complex breaks down and releases vitamin A more readily than the alcohol complex, so that under normal physiological conditions, the liver vitamin A will be used more than the plasma vitamin A which may actually be increased by small additions due to the de-esterification of liver vitamin A.

Recent Trends in Vitamin A Research

Two approaches may be distinguished as characteristic of vitamin A researches during the past decade or so. A large amount of research has been devoted to studying the effects of other factors, nutrients and non-nutrients alike, which may affect the optimum utilization of vitamin A in the body. Therc is also the more recent approach which seeks to find the best practical methods of supplementing vitamin A to the available feedstuffs with the view of obtaining the maximum performance of cattle.

The following paragraphs will recount, in a summary, some of the major nutrients and factors which have been shown to influence vitamin A utilization in the body.

Erwin et al. (1963) showed that the utilization of vitamin A by fattening steers was not affected by increased levels of protein. Also, it was shown in the same experiment that raising the energy content of the diet by means of fat without the addition of antioxidants would destroy the vitamin A.

With growing rats, or perhaps growing animals in general, the situation seems different. Anrich and Pederson (1956) increased the vitamin A stores of growing rats by increasing the protein in the diet, but decreased it by increasing the caloric intake. Also, Virginia et al. (1964) have shown that the quality of the protein is also important in the storage of vitamin A in the rat, while Guha et al. (1964) and Roxas et al. (1964) have both identified vitamin A with tissue synthesis of protein.

Kohlmeier and Burroughs (1962) have shown that, in the steer, addition of vitamin E improves vitamin A storage. This had been known in the rat for a long time (Daviesand Moore, 1941).

The relationship between nitrates and vitamin A has been studied perhaps more than any other factor. O'Dell et al. (1960) demonstrated increased depletion of vitamin A stores in cattle by including 0.3% of nitrate in the diet. Weichenthal et al. (1963) showed that 1.16% of sodium nitrate in steer fattening rations decreased the average daily gains by 0.5 lb. High levels of nitrate in silage crops, of the order of less than 1% KNO_3,have also been shown to cause rapid depletion of vitamin A stores (Smith et al., 1961; Jordan et al., 1961; and Jordan et al., 1963).

Lewis (1951) has shown that nitrate and nitrites are reduced very rapidly to ammonia in the rumen, but the small amount of nitrite that escapes into the blood can cause oxidation of much of the hemoglobin to methemoglobin. Also, the methemoglobin levels declined to insignificant levels after 6-7 hours. It seems then that the two factors involved in the nitrate problem are the levels of nitrate or nitrite and the length of time the animal is exposed to the feed.

In vitro experiments have also shown that rumen micro-organisms may destroy part of the ingested vitamin A (Klatte et al., 1963; Keating et al., 1964; and Pugh et al., 1962).

Research is scanty on the effects of antibiotics on vitamin A nutrition. Richardson and his associates (Richardson et al., 1961 and Richardson and Smith, 1964) secured optimum average daily gains from fattening steers when the average daily ration was supplemented with pellets containing dehydrated alfalfa meal, crystalline vitamin A and 70 mg. of aureomycin. Perry et al. (1962) also found similar effects, but it was noted in their experiment that the antibiotic actually caused a depressed growth rate when it was fed in a ration unsupplemented with vitamin A.

Present Trends in Vitamin A Nutrition

The story of vitamin A nutrition over the years has been a dreary one. Researchers have always been aware of the limitations of applying the results of Guilbert and his associates and even the standards of the National Research Council. But meanwhile too many interacting factors seemed to confuse the issues and much time was spent in studying these factors.

Things took a new turn when Jordan et al. (1963) reported that cattle on a corn silage wintering ration had come down with typical vitamin A deficiency symptoms even though the silage supplied not less than 175 mg of carotene per head daily, an amount which was about ten times the requirements recommended by the National Research Council (1958). It was also noted that some steers failed to gain in body-weight over a 28-day period and the plasma and liver vitamin A concentrations had decreased to very low levels.

Even though the experiment might be considered as warranting a revision of the National Research Council standards, the claims seemed rather excessive.

Klosterman et al. (1963) using rather poor corn silage which supplied about 30 mg of carotene per head daily, were able to keep steers on wintering rations for about 182 days with average daily gains of 2.36 lbs, reportedly without any signs of vitamin A deficiency. However, the gains were slightly improved to 2.42 lbs with the addition of 20,000 I.U. of vitamin A, or the equivalent, 50 mg of carotene.

Richardson and Smith (1964) also maintained fattening steers for 154 days without any vitamin A deficiency symptoms. The diet contained 22 lbs of sorghum silage which supplied about 44 mg of carotene as well as 25 mg of carotene from 0.5 lbs of alfalfa meal. The average daily gains were about 2.5 lbs.

The present experiment was designed to compare the performance of fattening steers when fed 10 or 20 lbs of silage and supplemented with 0, 15,000 or 30,000 I.U. of vitamin A. The wintering phase was also designed to compare the effect of feeding 4 or 8 lbs of grain, on the performance of the steers during the fattening phase. Performance was evaluated in terms of average daily gains and carcass characteristics, and vitamin A sufficiency of the diet was evaluated in terms of the performance characteristics as well as the liver storage of vitamin A and carotenoids at the time of slaughter.

MATERIALS AND METHODS

Wintering Phase

Sixty Hereford steer calves weighing between 450 and 550 lbs, were obtained from Warner Ranch in Rice County, Kansas, in November, 1963. The animals were divided into 6 lots of 10 animals each, and in such a way that the average weights of the lots obtained from two consecutive weighings during the last two days preceding the start of the experiment, did not differ by more than 5 lbs. The lots were numbered consecutively from 7 to 12 according to the serial numbers of the pens allocated to them.

The wintering phase of the experiment lasted from November 12, 1963, to March 5, 1964, a period of 114 days. All animals were fed sorghum silage *ad libitum*, and in addition, lots 7, 8 and 9 received 8 lbs of coarsely ground sorghum grain per head per day. These lots were designated as the high winter-grain group (HWG). Lots 10, 11, and 12 were the low winter-grain group (LWG) and received 4 lbs of the grain per head daily. All rations were supplemented with soybean oil meal at the rate of one pound per head per day. Salt and bone meal were provided free-choice and good drinking water from self-operating taps was always available.

The animals were fed twice daily between 7 and 8 a.m. and 4 and 5 p.m. The protein supplement was fed only in the mornings along with half of the allowance of silage and grain. The rest was fed in the evening. Sorghum silage was fed throughout the wintering phase.

The animals were weighed every 28 days after November 12. The silage was analyzed regularly at monthly intervals to determine its contents of carotene and dry matter. A complete proximate analysis was also run on part of the collected samples. However, owing to some initial difficulties, no useful analyses could be made until March, and so not much was known about the sorghum silage during the winter as a whole.

Fattening Phase

At the end of the wintering phase, all animals were weighed on March 5 and March 6, and the average of the two weights was used as the starting weight of the individual animal. The animals were regrouped into 6 lots of 10 animals, and again numbered consecutively from 7 to 12. The re-grouping was such that each lot contained 5 animals from the low winter-grain group and 5 from the high winter-grain group, again allowing only about 5 lbs differences among the lot average weights.

Lots 7, 8, and 9 were started on a low-silage regimen of 10 lbs per head per day while lots 10, 11, and 12 received 20 lbs per head per day. After about one month, sorghum silage was used up and so corn silage was substituted for it. The corn silage was considered rather poor. It was intended to keep the animals on these levels of silage throughout the experiment but owing to difficulty in maintaining an average daily intake of 20 lbs in lots 10 and 11, the levels were reduced in all the high-silage groups. The allowance of the low-silage groups was accordingly reduced to about half of the highest intake in the high-silage group. By the beginning of July, the low-silage groups were receiving 7 lbs of silage per head daily, while lots 10, 11, and 12 received respectively 10, 12, and 14 lbs daily. Lot 12 could have consumed more but it was not advisable to feed it liberally since that would be contrary to the purpose of the experiment.

Sorghum grain was fed ad libitum to all lots both in the morning and evening. The animals were started from 9 lbs of grain per head daily which was increased by about 1 lb every day up to an average daily intake of about 16 lb, to the point where the bunk was barely cleared. Despite this precaution, some animals had digestive disturbances during the first month. The supplement, in the form of pellets, was fed at the rate of 1.5 lbs per head per day in the morning only.

Proximate analysis was run on the three major ingredients: silage, grain and supplement. In addition, the silage was quantitatively analyzed for carotene regularly at predetermined intervals and the supplement for both carotene and added vitamin A.

Tables 1, 2, 3, and 4 summarize the important information on the feeds.

The experiment was terminated on September 18. The average of the two weights of each animal measured on the last two consecutive days of the experiment was recorded as its finished or feed-lot weight. Twenty-four hours elapsed between the termination of the experiment and the slaughter. The animals were given only prairie hay and water during this period. The animals were slaughtered in a commercial plant, A. J. Maurer and Sons, Kansas City, Missouri.

All the carcass data reported here were obtained by personnel from the Animal Husbandry Department, with the co-operation of the staff of the packing house. Liver samples for vitamin A analysis were taken from the small lobe.

Table 1. Periodical analyses of silage and sorghum grain.

Period March-Sept. 1964	Silage %					Mg/lb	Sorghum Grain %				
	DM	CP	CF	EE	Ash	Car.	DM	CP	CF	EE	Ash
March	25.0	1.76	6.5	0.66	2.4	5.4	88.5	8.4	2.5	3.05	1.3
April	27.3	1.64	7.5	0.57	2.4	2.5					
May	34.0	2.46	9.6	0.68	3.1	2.5					
June	34.3	2.32	9.9	0.64	3.4	1.9	87.0	7.8	1.7	2.71	1.35
July	39.5	2.47	10.7	0.89	3.7	3.4					
August	35.4	2.29	9.5	0.85	2.0	1.3					
Sept.	34.1	2.43	7.8	0.69	2.7	2.5	89.5	11.2	8.1	3.45	1.7
Average	32.6	2.70	8.6	0.71	2.8	2.8	88.3	9.1	4.1	3.07	1.45

Table 2. Composition of supplement.

Ingredient	%
Soybean oil meal	60.5
Dehydrated alfalfa meal[a]	30.2
Molasses[b]	4.4
Ground limestone	4.4
Aurofac-10[c]	2.5
	100.0

Added per lb
Vitamin A[d]: 10,000 I.U. (Supplement B, Lots 8 and 11)
Vitamin A : 20,000 I.U. (Supplement C, Lots 9 and 12)

[a] Alfalfa meal was from different sources; carotene contents varied with different supplements. See Table 3.

[b] Molasses added as binding agent in pelleting.

[c] Crude material calculated to provide, on the average, 70 mg of aureomycin in 1.5 lb supplement per head daily.

[d] Vitamin A supplied as the palmitate ester by Hoffmann-LaRoche Inc., Nutley 10, New Jersey.

Table 3. Periodical analyses of supplement.[1]

Period: March–Sept. 1964	Supplement A % DM	CP	CF	EE	Ash	Mg/lb Car.	Supplement B % DM	CP	CF	EE	Ash	Mg/lb Car.	I.U./lb Vit. A	Supplement C % DM	CP	CF	EE	Ash	Mg/lb Car.	I.U./lb Vit. A
March	90.4	28.1	9.5	2.12	9.8	—	91.2	27.7	9.8	2.09	10.6	—	—	92.2	27.6	9.7	2.45	10.7	—	—
April						6.0						12.9	5,815						5.0	10,670
May						5.4						10.1	7,976						3.8	16,330
June						4.9						7.4	4,830						4.5	9,150
July	91.0	27.5	9.5	2.17	10.5	4.4	89.9	28.3	9.6	2.01	10.8	12.3	10,113	91.0	27.6	9.4	2.15	10.5	5.1	21,365
Aug.						4.1						6.3	—						3.7	—
Sept.	87.7	27.5	9.5	2.70	10.5	3.7	91.6	27.1	9.5	2.94	10.6	4.6	7,907	90.1	26.6	9.6	2.30	10.5	2.2	15,705
Average	89.7	27.7	9.5	2.33	10.3	4.75	90.9	27.7	9.6	2.68	10.3	8.93	9,100	91.1	27.3	9.6	2.5	10.5	4.5	18,535

[1] Supply of ingredients and pelleting done by Feed and Flour Milling Department, K.S.U.
Supplement A contained no vitamin A (for lots 7 and 10)
Supplement B contained 10,000 I.U. of vitamin A per lb (for lots 8 and 11)
Supplement C contained 20,000 I.U. of vitamin A per lb (for lots 9 and 12)
Carotene content assumed due to alfalfa meal. Estimated as mg beta carotene/lb.

Table 4. Estimated average daily intake of carotene and vitamin A in the lots.

Ingredient	Intake per head per day by lots					
	7	8	9	10	11	12
Silage, lbs	9.0	8.9	9.0	14.3	13.6	15.8
Supplement, lbs	1.5	1.5	1.5	1.5	1.5	1.5
Carotene,[a] mg	32.32	38.27	34.35	47.17	41.43	53.39
Vitamin A equivalent of carotene[b]	12,928	15,328	12,780	18,868	20,592	20,396
Preformed vitamin A I.U.[c]	0	13,650	27,802	0	13,650	27,802
Total vitamin A equivalent, I.U.[d]	12,928	28,978	40,582	18,868	34.242	48,198

[a]Value is obtained by multiplying wt of silage by carotene content of silage (Table 1) and adding product to corresponding value for the supplement (Table 3). For example, for Lot 7, (9.0 x 2.8) + (1.5 x 4.75) = 32.32.

[b]Value in (a) is multiplied by 400, assuming 1 mg of beta carotene = 400 I.U. Vit. A.

[c]Value is obtained by multiplying average vitamin A content per lb in Table 3 by 1.5. Lots 7 and 10 were not supplemented. Supplement B for Lots 8 and 11; supplement C for lots 9 and 12.

[d]Value = sum of b and c.

Chemical Analysis of the Feed

Grain and Silage. Silage samples were collected in quart-size sampling jars at the time of feeding, soon after the silage came out of the silo. About 500 gm samples were dried at 100°C for 24-36 hours in a hot-air-blast oven.

Part of the fresh sample was immediately prepared for carotene determination according to the A.O.A.C. procedure 39.015b (1960). The rest of the sample was used for proximate analysis, using the relevant procedures in the A.O.A.C. chapter 22 (1960). The same procedures were used for the proximate analysis of the grain. In the crude fiber determination, it was found more convenient and faster to filter the alkali digest through a neatly fitting linen cloth placed in a Buchner funnel. Apparently no fiber was lost by this method of filtering, since the filtrate was quite clear.

Analysis for Vitamin A and Carotene in Supplement. The A.O.A.C. methods 39.008-39.013 (1960) were followed closely. For a long time it was only possible to obtain about 50 per cent recovery of the expected quantity of vitamin A in the feed. Apparently the technique for removing the hexane-extract (of the vitamin) from the extraction flask into the separatory funnel was rather poor. Upon consultation with Parrish,[1] the following technique was adopted as described in the connotated diagram in Fig. 1.

By this method, 4 or 5 hexane extractions were necessary to remove all the vitamin in the original extract.

Examination of Table 3 shows that the last two values of vitamin A (for July and September) appear as more reasonable estimates of the vitamin A in the feed when allowance is made for some deterioration during storage. Also, the values for the previous months, even though they may appear incongruous, should probably indicate that the vitamin A might have been quite stable during those months. The variation in the values is apparently due to changes in techniques in search of a better one.

For these reasons the average value of vitamin A used in subsequent discussions is the mean of the last two determinations. As a further check

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[1] D. B. Parrish, Department of Biochemistry, K.S.U., 1964.

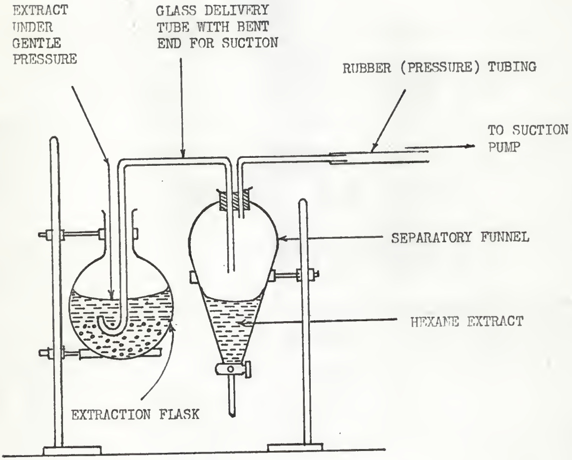

Fig. 1. Diagram showing arrangement of apparatus for removing hexane-extract of vitamin A into separatory funnel.

on these values, determinations were made on samples from the feed mill that had been kept at room temperature in the laboratory. The results were:

Supplement B: 9,689 I.U. vitamin A/lb

Supplement C: 17,960 I.U. vitamin A/lb

These figures compare well with the averages in Table 3.

Judging from the September analysis, it seems that about 25-30% of the estimated potency of the vitamin had been lost by the end of seven months. But from the estimated averages, it seems the manufacturers had compensated for these losses by understating the potency of the fresh product. Whenever the vitamin A determination appeared unacceptable, a check was made on the result for beta-carotene by using the A.O.A.C. method 39.015 (1960); but generally the two results agreed reasonably well.

Analysis of Liver for Vitamin A and Carotenoids

The method used was the routine procedure used in our Animal Nutrition Laboratory. It is a slight modification of the method used by Heaton _et al._ (1957) which was probably developed from the old method of Davies (1933).

To 5-10 gm. sample of the liver were added 10 ml of 50% (w/v) of potassium hydroxide and 10 ml of 95% (v/v) of ethyl alcohol. The mixture was boiled gently for 30 minutes on water bath and under reflux. It was then extracted twice with about 90 ml of dry ether in two portions. The ether-extract was washed free of alkali and alcohol with water and then dried with anhydrous sodium sulfate. Vitamin A was then determined by the usual Carr-Price procedure. Carotenoids were determined by evaporating off the ether and taking up the residue in n-hexane. This procedure permitted the use of the carotene graph prepared for the feed analysis.

Occasionally, when the carotenoid extract was fractionated through aluminum oxide column, it was found that the beta-carotene content ranged between 33 and 40%.

RESULTS

Visual Observations on the Live Animals

The animals in all the lots came through the winter in good, uniform condition. It was not easy to distinguish animals in one group from those in the other group by external appearances.

After about one month on the fattening ration, two animals in lot 11 developed mild bloat. One of them responded well to mineral-oil drench but the other animal continued to bloat occasionally, but not seriously enough to warrant discarding it from the experiment.

Later, in June, one steer in lot 8 died of non-parasitic gastroenteritis. The exact cause could not be determined by post-morten examination.

When the level of silage was reduced to 7 lbs per head daily in the low-silage group, the animals began to chew on the fence. It was not too serious, but it was noticeable, especially in lot 9.

All the animals appeared to have come through the summer without any untoward reactions, but during the first week of September, the animals in lot 7 appeared listless. Their coats looked ruffled and their appearances were stark. Grain consumption was also much reduced. Towards the close of the experiment, one animal from this lot became ill and was removed from the experiment. It died one week afterwards, and post-mortem examination revealed a case of urinary calculi.

Apart from these occurrences, no other important changes in the animals were observed. There could not have been any night-blindness since these animals walked through the labyrinth of the holding pens without difficulty at dusk when they were being loaded for transport to market.

Summary Results of Wintering and Fattening Phases

Table 5 is a summary of the pertinent results obtained during the wintering phase. It includes the average daily rations of the six lots of animals, as well as the estimated feed cost per 100 lbs of body-weight gained.

Table 6 contains similar information obtained during the fattening phase. In addition, it contains summaries of the carcass characteristics as well as the liver storage of vitamin A and carotenoids.

The subsequent paragraphs describe in detail some of the results summarized in Tables 5 and 6.

Growth

Table 7 is a summary of the average weights of the animals in the six lots during the wintering phase. The values were calculated from the weights of the individual animals measured at 28-day intervals.

Comparison of the final average weights shows that, at end of the wintering phase, the animals fed the high-grain ration weighed, on the

Table 5. Summary results of wintering phase. (November 12, 1963 to March 6, 1964)

Groups	High winter-grain			Low winter-grain		
Lot No.	7	8	9	10	11	12
No. of steers per lot	10	10	10	10	10	10
Av. initial wt, lbs	489.5	486.0	486.5	487.0	487.0	487.5
Av. final wt, lbs	751.5	745.0	763.0	730.5	737.0	732.0
Av. daily gain, lbs	2.28	2.26	2.40	2.12	2.17	2.13
Av. daily ration, lbs:						
Sorghum silage	24.2	24.3	24.3	29.8	29.7	29.7
Sorghum grain	7.9	7.9	7.9	4.0	4.0	4.0
Soybean oil meal	1.0	1.0	1.0	1.0	1.0	1.0
Feed per cwt. gain, lbs						
Sorghum silage	1063.0	1077.0	1010.0	1405.0	1368.0	1399.0
Sorghum grain	344.3	348.3	326.2	188.9	184.0	188.1
Soybean oil meal	43.9	44.4	41.6	47.2	46.0	47.0
Feed cost per cwt gain	$ 11.97	12.35	10.22	10.02	10.02	10.24

average, about 20 lbs more than those fed the low-grain ration.

Table 8 is a summary of the calculated monthly weights of the steers during the fattening phase. (The fattening phase was not a direct continuation of the wintering phase. Each lot consisted of equal numbers of animals from both the high-and low-grain winter groups.) During the fattening phase, the six lots of animals were divided into low-and high-silage groups.

Comparison of the average final weights shows that, on the average, steers fed the high-silage rations were about 22 lbs heavier than those fed the low-silage rations.

Within each group, the lot averages of the final weights were highest where the ration was supplemented with 30,000 I.U. of vitamin A and lowest

Table 6. Summary results of fattening phase. (March 6 to September 18, 1964—197 days)

Groups	Low-silage Group			High-silage Group		
Lot No.	7	8	9	10	11	12
Steers per lot	9	9	10	10	10	10
Initial wt per steer, lbs	741	745	742	742	743	744
Final wt per steer, lbs	1106	1104	1131	1105	1130	1167
Av. daily gain, lbs	1.85	1.83	1.92	1.84	1.97	2.15
I.U. Vit. A added daily	0	15000	30000	0	15000	30000
Av. daily ration, lbs:						
Supplement	1.5	1.5	1.5	1.5	1.5	1.5
Sorghum grain	14.8	14.2	15.2	13.8	13.9	15.2
Silage	9.0	8.9	9.0	14.3	13.6	15.8
Feed per cwt gain lbs:						
Supplement	81	82	76	81	76	70
Sorghum grain	800	680	710	700	660	640
Silage	486	492	457	775	777	728
Feed cost per cwt gain	$ 19.92	20.27	19.49	20.49	20.31	19.13
Shrink to market %	2.51	2.26	1.68	2.40	2.74	2.10
Av. hot carcass wt, less 2%	688.2	674.2	698.3	693.1	693.1	722.3
Dressing %, feedlot wt	64.1	61.08	61.74	62.70	61.31	61.89
Dressing %, market wt	64.4	62.49	62.80	64.24	63.04	63.22
Av. fat thickness, 12th rib, in.	0.93	1.05	1.06	1.00	1.05	1.03
Av. size rib-eye, sq.in.	11.79	11.10	11.28	11.99	11.45	11.43
Carcass grades:						
Top Choice	—	1	—	—	—	1
Av. Choice	2	2	—	3	—	1
Low Choice	5	4	5	6	4	4
Top Good	2	2	4	1	6	4
Av. Good	—	—	1	—	—	—
Low Good	—	—	—	—	—	—
Av. Liver wt, lbs	11.11	10.36	10.71	10.19	10.45	10.88
Vit. A per gram liver, I.U.	0.77	16.03	30.06	0.91	14.87	34.36
Total Vit. A per liver, I.U.	4112	76623	148145	4463	71318	166446
Carotenoids per gram liver, mcg	1.06	1.31	0.77	1.25	1.11	1.21
Total carotenoids per liver, mg	5.3	6.2	3.9	6.1	5.2	6.0

Table 7. Monthly average weights (lbs) of steers during the winter. (November 11, 1963 to March 5, 1964--114 days)

Period	Lots					
November 12-	High winter-grain			Low winter-grain		
March 15	7	8	9	10	11	12
11/12/63	489.5	486.0	486.5	487.0	487.0	487.5
11/12-12/10	545.5	544.0	552.5	562.5	561.0	551.0
12/11-1/7	620.5	620.0	631.1	624.0	615.0	613.0
1/8-2/4	690.0	686.5	699.5	675.0	675.5	671.5
2/5-3/5	751.5	745.0	763.0	730.5	737.0	732.0

High winter-grain = 8 lbs of sorghum grain/head/day

Low winter-grain = 4 lbs of sorghum grain/head/day

Table 8. Monthly average weights (lbs)of steers during fattening phase. (March 6 to September 18, 1964--197 days)

Period	Lots					
March 6 -	Low-silage group			High-silage group		
Sept. 18, 1964	7	8	9	10	11	12
3/5	740.6	745.0	742.0	742.5	743.0	744.0
3/6-4/3	795.0	795.0	785.5	808.0	809.5	813.0
4/4-5/1	885.0	872.5	873.0	895.0	885.0	907.5
5/2-5/29	934.5	925.5	963.0	939.5	934.5	959.5
5/30-6/26	983.5	963.3	983.5	984.5	984.5	1027.0
6/27-7/24	1029.5	1025.0	1041.5	1042.0	1043.0	1082.0
7/25-8/21	1076.5	1073.3	1102.0	1098.7	1118.5	1162.5
8/22-9/18	1106.0	1104.0	1131.0	1105.5	1130.5	1167.0

Low-silage group received an average of about 9 lbs of corn silage/head/day.
High-silage group received an average of about 14-15 lbs of corn silage/head/day. (cf. Table 6)

Lots 7 and 10 received no vitamin A supplement.
Lots 8 and 11 received 15,000 I.U. vitamin A/head/day.
Lots 9 and 12 received 30,000 I.U. vitamin A/head/day.

where no vitamin A supplement was fed, except for the apparent discrepancy in lot 8.

A comparison of the average weights of lots 8 and 9 with lots 11 and 12 suggests that the level of silage in the ration did affect the effectiveness of the vitamin A supplement in inducing growth response. This statement appears tangible when lots 9 and 11 are compared on the basis of the total vitamin A intake (Table 4) and the average final weights (Table 8).

Figure 2 is a graphical comparison of the growth pattern of the low-and high-silage groups.

Average Daily Weight Gains

Table 9 summarizes the average daily gains of the steers during the wintering phase. The lot average daily gains were calculated for the individual weights of the steers taken at 28-day intervals.

Table 9. Average daily gains (lbs) of steers during the wintering phase. (November 11, 1963 to March 5, 1964)

	High-grain Group			Low-grain Group		
	Lot			Lot		
Period	7	8	9	10	11	12
11/12 - 12/10	2.00	2.07	2.36	2.70	2.64	2.27
12/11 - 1/7	2.68	2.71	2.82	2.20	1.93	2.21
1/8 - 2/4	2.48	2.38	2.43	1.82	2.16	2.21
2/5 - 3/5	1.98	1.89	2.05	1.79	1.98	2.09
Lot Average	2.28	2.26	2.41	2.12	2.17	1.95

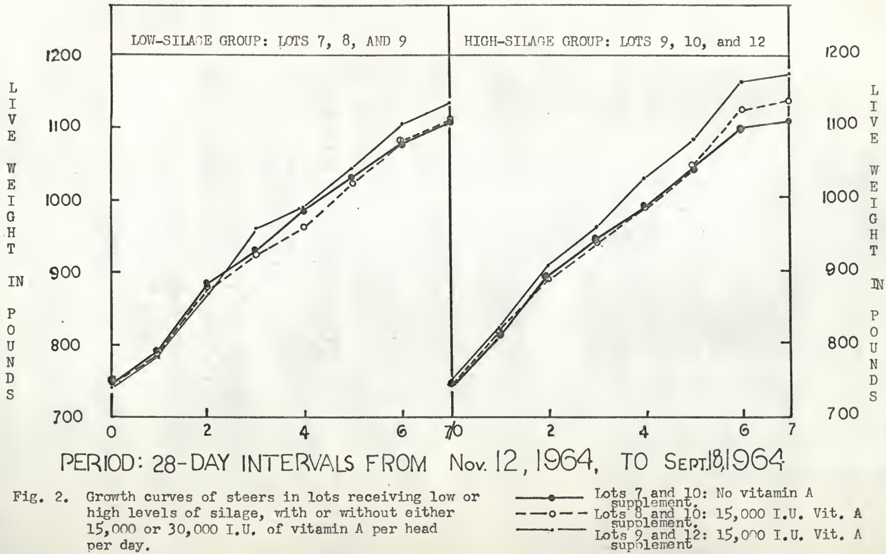

Fig. 2. Growth curves of steers in lots receiving low or high levels of silage, with or without either 15,000 or 30,000 I.U. of vitamin A per head per day.

Statistical analysis of the data showed that there were no significant differences among the means of the lot average daily gains during the wintering phase. This was probably due to large variations within the lot averages. Also, the estimated average daily gains of all the lots varied significantly ($P < 0.01$) from one period to the other.

However, the general trend was that the animals on the high-grain ration tended to gain in weight at a faster rate than those on the low-grain ration.

Table 10 summarizes the lot averages of the calculated average daily gains of the steers during the fattening phase. Table 11 reports the same average daily gains but on the basis of individual steers. The figures in Table 11 were used for statistical analysis.

Table 10. Average daily gains (lbs) of steers during the fattening phase, on lot basis.[1] (March 6 to September 18, 1964)

	High-silage Group			Low-silage Group		
	Lot			Lot		
Period	7	8	9	10	11	12
3/6 - 4/3	1.84	1.91	1.55	2.34	2.38	2.46
4/4 - 5/1	3.21	2.68	3.13	3.11	2.70	3.38
5/2 - 5/29	1.77	1.89	3.25	1.59	1.77	1.86
5/30 - 6/26	1.75	1.98	1.70	1.61	1.79	2.41
6/27 - 7/24	1.64	2.21	2.07	2.05	2.09	1.96
7/25 - 8/21	1.68	2.24	2.16	2.02	2.70	2.87
8/22 - 9/18	1.16	0.58	1.04	0.24	0.43	0.16
Average	1.85	1.83	1.92	1.84	1.97	2.15

[1] Figures of average daily gains were obtained by dividing the lot average gain over a 28-day period by the 28 days that had elapsed.

Table 11. Average daily gains[1] (lbs) of steers during the fattening phase.

Description	Low-silage Group			High-silage Group		
	Lot			Lot		
	7	8	9	10	11	12
LWG	2.08	1.83	2.31	2.21	2.08	2.06
	1.70	--*	2.18	1.68	1.95	1.90
	1.95	1.75	1.80	1.85	2.01	2.03
	2.18	2.00	1.80	1.23	1.37	2.23
	--*	1.65	2.03	1.75	2.03	1.78
HWG	1.77	1.78	1.93	2.26	2.11	2.56
	1.67	1.98	1.95	1.77	2.34	2.08
	1.70	1.88	1.47	1.98	1.88	2.23
	1.83	1.78	1.88	1.90	1.93	2.46
	1.80	1.75	1.90	1.73	1.98	2.13
Av. LWG	1.98	1.81	2.02	1.74	1.89	2.00
Av. HWG	1.75	1.83	1.82	1.93	2.05	2.30
Lot average	1.85	1.83	1.92	1.84	1.97	2.15
Over-all av. LWG	1.91					
Over-all av. HWG	1.93					

[1] Average daily gains of steers were obtained by subtracting average initial weight of steers from the final and dividing the difference by the total number of days that the steers were on experiment.

*Blank spaces are due to steers which died during the experiment.

LWG = Low winter-grain subclass.

HWG = High winter-grain subclass.

The differences among the lot means of the average daily gains during the fattening phase were statistically significant at the level of $P < 0.05$. However, there were no significant differences between the gains of lots 11 and 9, or among lots 7, 8, and 10. Lot 12 gained significantly more than the rest. Thus, the animals on the unsupplemented diets as well as those in the low-silage group and supplemented with only 15,000 I.U. of vitamin A, gained significantly less ($P < 0.05$) than the rest.

The statistical analysis showed further that there was no significant advantage derived from feeding 8 lbs of grain in the winter instead of 4 lbs, but there was a distinct advantage ($P<0.01$) when the high-silage rations were supplemented with vitamin A.

Figure 3 is a graphical representation of Table 11and it shows the trends in the average daily gains. It seems the average daily gains of the animals in the high-silage group were more uniform as compared with those of the animals in the low-silage group. Also, whereas the animals in the high-silage group increased their average daily gains during the first month on the fattening ration, those in the low-silage group suffered a slight decrease. Probably, those animals in the low-silage group were too slow in adjusting to the fattening ration. After the first month, the trends of the lots in both groups were similar. Lots 9 and 12 tended to sustain higher rates of gain longer or more frequently than the rest.

The "zig-zags" in the curves were primarily the result of the variations in the observed weight gains, but it is likely that daily variations in the weather or some genetic differences contributed to such variations.

Grain Consumption

Table 12 summarizes the total and average rates of consumption of sorghum grain by the six lots of animals.

There were no statistical differences among the lots in the monthly rate of grain consumption, and the over-all average consumption in the high-and low-silage groups were practically the same. The fact that lots 9 and 12 in the high-vitamin A sub-groups consumed equal quantities of grain was interesting, for it indicated that any differences between the

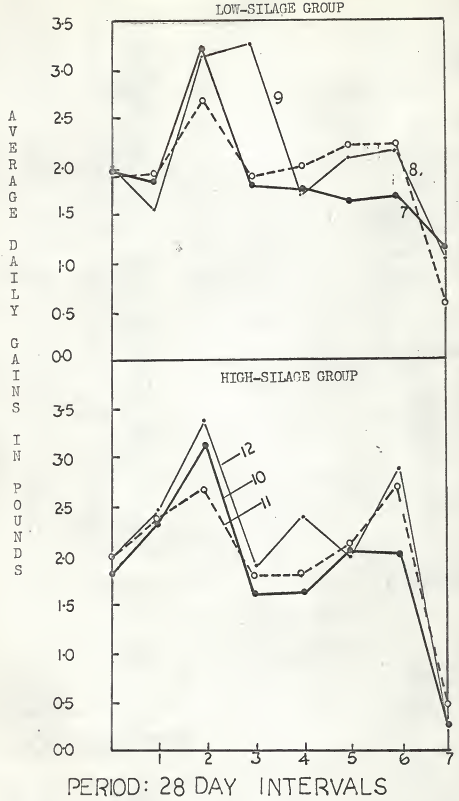

Fig. 3. Trends in average daily gains during the fattening phase.

Lots 7 and 10 Lots 8 and 11 Lots 9 and 12

Table 12. Monthly rate of grain consumption (lbs) by lots during fattening phase. (March 6 to September 18, 1964)

	Low-silage Group			High-silage Group		
	Lot			Lot		
Period	7	8	9	10	11	12
3/6 - 4/3	3720	3580	3640	3630	3580	3535
4/4 - 5/1	4245	4160	4100	4110	4115	4080
5/2 - 5/29	4680	4385	4405	4210	3390	4600
5/30 - 6/26	4517	3783	4663	4038	4125	4625
6/27 - 7/24	4085	3585	4365	3785	4030	4310
7/25 - 8/21	4070	3665	4390	3715	3810	4290
8/22 - 9/18	3774	3690	4468	3667	4379	4413
Total	29087	26348	30031	27164	27429	29853
Steer Av.[a]	14.8	14.2	15.2	13.8	13.9	15.2
Average of Low-silage Group			14.7			
Average of High-silage Group			14.3			

[a] Steer average denotes per head average daily consumption corrected for steers that died in lots 7 and 8.

performances of these lots due to a nutritional effect, could be attributed primarily to the differences in silage consumption, since all other treatments were equal.

Table 13 lists the calculated efficiencies of grain utilization among the lots. Efficiency is reported as the pounds of grain per pound of weight gain, reduced to individual basis. By the analysis of variance technique, no significant differences among the lot means were found. However, two other observations may be mentioned. If the figures for the last month are excluded and the net averages over the first six months are compared, it is found that the high-silage lots had higher efficiencies than the low-silage lots, and the order of the efficiencies followed the

Table 13. Efficiency of grain utilization during fattening phase. (Lot averages of lbs of grain per lb of gain)

	Low-silage Group			High-silage Group		
	Lot			Lot		
Period	7	8	9	10	11	12
3/6 - 4/3	7.0	6.5	8.1	5.4	5.2	4.9
4/4 - 5/1	4.7	5.6	4.7	4.7	5.5	4.3
5/2 - 5/29	9.5	8.3	4.9	9.5	8.4	8.9
5/30 - 6/26	9.3	7.6	9.7	9.0	8.3	6.9
6/27 - 7/24	8.9	6.4	7.6	6.6	6.9	7.9
7/25 - 8/21	8.7	6.5	7.3	6.6	5.1	5.4
8/22 - 9/18	11.7	25.0	15.4	54.6	36.4	99.0
Average[a]	8.5	9.4	8.3	13.8	11.8	19.6
Average[b]	8.0	6.8	7.1	7.0	6.6	6.4

[a] Over-all lot average used for statistical analysis.

[b] Lot average without figure for last month.

order of the intake of "total vitamin A" (Table 4). Inclusion of the last month's figures in the calculation shows that the high-silage lots were less efficient than the low-silage lots.

A careful comparison of the estimated "total vitamin A" intake in Table 4, the average final weights (Table 6) and the feed efficiencies reported in Table 11 permit the statement that the higher levels of vitamin A intake caused the animals to grow faster and attain their finished weights earlier than those on low levels of "vitamin A."

Figure 4 is a graphical representation of Table 13, and it shows that there were more variations in feed utilization in the low-silage groups than there were in the high-silage group.

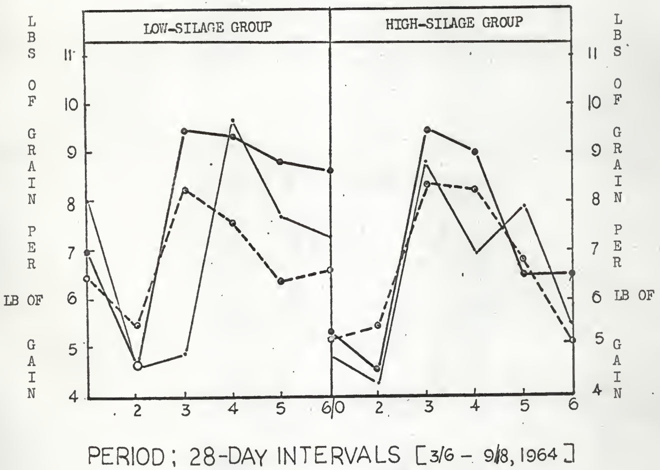

Fig. 4. Efficiency of grain utilization by groups of steers during fattening phase.

Carcass Characteristics

Carcass Dressing Percentage. Table 14 summarizes the data on the carcass dressing percentage. There was a significant difference ($P < 0.01$) between the means of the group of animals that received 8 lbs of grain in winter and those that received 4 lbs of grain. Among the low-silage group, the advantage belonged to those fed the low-grain rations, but in the high-silage group, it was the reverse. However, the effect of the interaction was not statistically significant. Also, the differences among the lot means were not statistically significant. It was interesting to find that animals in lots 7 and 10 which did not receive any vitamin A supplement had a higher dressing percentage than animals in any of the other lots.

Rib-eye Area. Table 15 is a summary of the data on the rib-eye area. There were no significant differences among the lot means as well as the subclass means. In other words, neither the levels of grain in the winter ration nor vitamin A in the fattening ration had any significant effect on the area of the rib-eye muscle.

There was a tendency towards a lot x subclass interaction. In the low-silage group, those animals which were wintered on the low-level of grain had slightly larger rib-eye areas than those on the high level of grain, but in the high silage group, there was a tendency towards the reverse.

Back-fat Thickness. The measurements of the back-fat thickness are presented in Table 16.

The lot means as well as the subclass means did not differ significantly at any reasonable level of rejection, nor was there any subclass x lot interaction.

Table 14. Carcass dressing percentage.[a]

Description	Low-silage Group Lot 7	8	9	High-silage Group Lot 10	11	12
LWG[b]	64.3	60.8	64.0	63.4	66.0	63.7
	62.6	—	61.4	63.0	62.1	62.2
	72.2	65.6	63.1	65.2	64.6	64.8
	63.1	61.9	63.1	63.5	60.1	62.2
	—	62.0	63.6	63.8	63.4	62.6
HWG[c]	63.6	62.8	60.9	63.6	61.3	64.1
	63.1	56.2	64.3	66.1	63.7	63.7
	62.5	67.1	61.9	64.9	63.6	63.5
	64.8	64.3	61.8	63.0	63.1	64.1
	64.7	62.2	63.6	65.4	64.2	61.3
Av. LWG	65.5	62.6	63.0	63.8	63.2	63.1
Av. HWG	63.7	62.5	62.5	64.6	63.2	63.3
Lot Average	64.4	62.4	62.8	64.2	63.2	63.2
Over-all av. LWG			64.7			
Over-all av. HWG			63.5			

[a]Dressing % = chilled carcass weight divided by market (shrunk) weight and expressed as %.
Chilled carcass weight = hot carcass weight less 2% for estimated cooler shrink.

[b]LWG = Low winter-grain subclass (4 lb/head/day).

[c]HWG = High winter-grain subclass (8 lb/head/day).

Table 15. Rib-eye area at the 12th rib, measured in square inches.

Description	Low-silage Group			High-silage Group		
	Lot			Lot		
	7	8	9	10	11	12
LWG[a]	12.64	9.55	11.90	12.80	12.31	10.06
	12.68	—	10.70	12.90	11.59	11.64
	11.94	12.06	12.52	12.70	10.95	12.18
	12.75	10.71	12.08	10.44	11.43	11.08
	—	13.38	9.92	11.13	12.65	11.56
HWG[b]	12.27	10.14	11.57	12.81	10.16	11.67
	10.43	12.31	11.71	12.52	12.22	10.07
	11.34	10.40	10.01	12.31	9.18	11.25
	10.81	10.92	11.39	11.68	12.05	11.69
	10.55	10.15	11.04	10.75	11.99	13.09
Av. LWG	12.50	11.42	11.42	11.95	11.78	11.30
Av. HWG	11.08	10.78	11.14	12.01	11.12	11.55
Lot Average	11.79	11.10	11.28	11.99	11.45	11.43
Over-all av. LWG			11.56			
Over-all av. HWG			11.26			

[a] LWG = Low winter-grain subclass (4 lb/head/day).

[b] HWG = High winter-grain subclass (8 lb/head/day).

Rib-eye area was traced with the planimeter.

Table 16. Back-fat thickness at 12th rib, inches.

Description	Low-silage Group, Lot 7	8	9	High-silage Group, Lot 10	11	12
LWG[a]	1.27	1.13	1.37	1.28	1.30	1.10
	0.57	—*	1.09	0.66	0.90	0.82
	0.80	0.99	0.76	0.89	0.89	1.38
	0.78	1.13	1.03	0.81	0.58	0.93
	—*	0.67	1.68	1.62	1.33	0.93
HWG[b]	1.09	1.49	0.99	1.30	1.14	0.89
	1.04	1.13	0.98	0.89	1.03	1.04
	0.73	0.99	0.89	0.70	1.20	1.36
	0.99	0.90	0.90	0.81	1.12	0.95
	1.20	1.15	0.98	1.09	1.01	0.91
Av. LWG	0.85	0.95	1.18	1.05	1.00	1.03
Av. HWG	1.01	1.15	0.95	0.96	1.10	1.03
Lot Average	0.93	1.06	1.06	1.00	1.05	1.03
Over-all av. LWG			1.01			
Over-all average HWG			1.03			

[a]LWG = Low winter-grain subclass (4 lb/head/day).

[b]HWG = High winter-grain subclass (8 lb/head/day).

*Blanks denote steers that died during the experiment.

Grade. Table 17 is a summary of the carcass grades reported in Table 6.

Table 17. Summary of carcass grades on lot basis.

Lot No.	7	8	9	10	11	12
No. in choice grade	7	7	5	9	4	6
No. in good grade	2	2	5	1	6	4

If one should limit the desirable grades to the choice range, it would seem that those animals whose intake of 'total vitamin A' was low, had better grades on the whole than those fed high levels (cf. Table 4).

Liver Weight

The data on the liver weights are presented in Table 18.

Analysis of variance technique detected small differences among the lot means but the differences were insignificant.

There was approximately 0.95 lbs of liver per 100 lbs of body weight which was slightly less than the commonly quoted value of 1 lb of liver per 100 lbs of body weight.

Four livers were condemned, three for abscess and one for liver-fluke infection. Bohman et al. (1957) in comparing the effects of stilbestrol and chlortetracycline on steer performance, noted zero incidence of liver abscess in the groups fed the antibiotic. Although the same kind of antibiotic was fed in this experiment, the design of the experiment was different and would not permit any valid conclusion on the number of liver abscesses encountered.

Table 18. Liver weights, lbs.

Description	Low-silage Group Lot 7	8	9	High-silage Group Lot 10	11	12
	13.00	10.75	10.25	11.25	11.25	10.25
	10.50	—*	11.00	8.50	10.00	11.75
LWG[a]	10.50	9.50	10.50	11.50	10.00	13.25
	—*	11.25	—+	8.00	9.25	11.00
	10.50	9.50	10.75	10.00	11.75	9.25
	11.50[xx]	10.00	10.50	11.00	10.00	11.75
	10.50	10.00	11.25	10.50	11.75	11.50[1]
HWG[b]	10.50	12.50[xx]	10.25	—+	10.00	11.16
	12.75	9.25	10.75	10.25	9.75	10.75
	10.00	10.50	—+	11.50[xx]	10.75	10.50
Av. LWG	11.1	10.25	8.62	9.85	10.45	11.1
Av. HWG	11.05	10.45	10.69	11.06	10.65	11.12
Lot Av.	11.11	10.36	10.71	10.19	10.45	10.88
Over-all av. LWG			10.56			
Over-all av. HWG			10.75			

*Blank indicates steers that died during experiment.

+Blank indicates no value for liver lost in the packing house.

xxLiver condemned for abscess.

1Liver condemned for liverfluke infection.

aLWG = Low winter-grain subclass (4 lb/head/day).

bHWG = High winter-grain subclass (8 lb/head/day).

Liver Storage of Vitamin A

The liver storages of vitamin A are reported in Tables 19 and 20. In Table 19 the vitamin A contents are reported as concentrations per gram, which were the actual laboratory analytical results. The values reported in Table 20 are the product of the result in Table 19 and the total weight of the liver (Table 18 expressed in grams). The values in Table 20, therefore, represent the total liver storage of vitamin A, assuming a homogenous distribution of the vitamin in the liver.

Examination of the table shows that there were large variations in the levels of vitamin A storage even in the same subclass within a lot. However, the differences among the lot means were very highly significant (P 0.01). The means of lots 9 and 12 were significantly greater than the rest. In other words, the addition of 30,000 I.U. of vitamin A to the average daily rations of steers fed both the low and high-silage rations resulted in significantly high levels of liver vitamin A storage as compared with the results of vitamin A storage of steers receiving either the 0 or 15,000 I.U. of vitamin A per head per day. But at the 1% level of rejection, the difference between the results of the latter two groups was not significant.

There was no significant lot x subclass interaction, but as the results indicate, the animals wintered on the high-grain ration had slightly more liver stores of vitamin, on the average, than those wintered on the low-grain ration.

Statistical analysis showed further that the lot averages of liver vitamin A stores did not indicate linear or threshold effects when compared with the levels of silage or the supplemental vitamin A in the rations. Also, a comparison of Tables 20 and 11 indicates no apparent relationship between the levels of liver vitamin A storage and the average daily gains.

Table 19. Liver vitamin A storage, I.U./gm. (Analytical results)

Description	Low-silage Group			High-silage Group		
	Lot			Lot		
	7	8	9	10	11	12
LWG[a]	1.1690	7.796	20.860	2.5827	15.433	32.365
	0.1403	—*	40.383	0.4088	7.888	35.679
	0.7659	9.141	22.592	0.7889	16.653	8.285
	0.6648	11.679	—+	0.4286	2.955	22.862
	—*	33.513	50.011	0.8470	5.810	57.245
HWG[b]	0.7497	7.665	21.235	0.8471	7.622	21.666
	0.5097	26.730	24.082	0.8337	23.091	10.213
	1.5557	22.675	15.536	—+	34.179	5.246
	0.8826	17.580	45.752	0.4228	8.811	86.881
	0.6702	7.4869	—+	1.1007	26.270	63.158
Lot Average	0.77	16.03	30.06	0.91	14.87	34.36

[a] LWG = Low winter-grain subclass (4 lb/head/day).

[b] HWG = High winter-grain subclass (8 lb/head/day).

+Blank indicates no value for liver lost in packing house.

*Blank indicates no value for steer that died during experiment.

Table 20. Total liver vitamin A storage, I.U./liver.

Description	Low-silage Group Lot 7	8	9	High-silage Group Lot 10	11	12
LWG[a]	5568	38015	96988	13180	78755	150479
	2230	—*	201495	1576	35780	190161
	3648	39390	107599	4115	75540	49797
	3920	60922	—+	1555	12401	114073
	—*	144412	243864	3842	30964	240188
HWG[b]	3914	47675	101138	4226	34573	115477
	2428	121247	122889	3971	12070	53274
	7416	128567	88089	—+	155035	26553
	3879	73762	223097	1965	38968	423647
	4003	35659	—+	5740	128015	300808
Av. LWG	3842	70685	162487	4849	46688	148940
Av. HWG	4388	81384	133804	3976	73732	183952
Lot Average	4112	76623	148145	4463	71318	166446
Range	2230-7416	35659-144412	96988-243864	1576-13180	12070-155035	26274-423647
Over-all av. LWG			72973			
Over-all av. HWG			80206			

[a]LWG = Low winter-grain subclass (8 lb/head/day).

[b]HWG = High winter-grain subclass (4 lb/head/day).

+Blank denotes no value for liver lost in the packing house.

*Blank denotes no value for steer that died during the experiment.

Liver Storage of Carotenoids

Table 21 is a summary of the estimated total stores of carotenoids in the livers. The method of calculating the values was the same as described for vitamin A. Since the carotenoid extract is an undefined mixture which may include true carotenes (principally the alpha-beta- and gamma-isomers), xanthophyll, lycopene and such related yellow-colored compounds which may have only limited value as sources of vitamin A to the animal, not much confidence can be placed on the carotenoid values as a whole, especially when the levels are low. However, when the levels are high, it is probable that more beta-carotene will also be present.

Beta-carotene is considered more potent as a source of vitamin A than the other isomers, since theoretically one molecule of it can be converted into two molecules of vitamin A. However, the common practice in liver analysis has been to report the total carotenoid storage since some useful correlations have been obtained between such values and other measurements of the vitamin A status of cattle. Occasionally, when the carotenoid extract was passed through alumina column, and the beta-carotene was eluted with 4% acetone in n-hexane, it was found that the beta-carotene content was 33 to 40 per cent.

Statistical analysis of the total liver carotenoids showed no significant differences due to any of the parameters tested: lot, subclass and subclass x lot interaction.

However, it may be summarized from the table that the average stores in the high-silage group were generally higher than in the low-silage group, which is not unexpected. But the apparent discrepancy between lots 8 and 11

Table 21. Total storage of carotenoids, mg/liver.

	Low-silage Group			High-silage Group		
	Lot			Lot		
Description	7	8	9	10	11	12
LWG[a]	7.36	12.71	2.27	4.77	3.00	6.58
	4.22	—*	5.94	0.48	4.46	3.61
	3.65	6.07	4.06	8.54	5.22	8.64
	8.37	9.50	—+	6.62	5.76	4.47
	—*	3.76	4.30	4.93	4.92	4.69
HWG[b]	8.10	4.83	0.63	8.81	5.29	6.96
	3.15	6.02	3.70	7.07	5.66	7.34
	3.78	3.99	5.66	—+	5.24	5.65
	3.40	4.36	4.45	6.09	4.86	6.26
	5.73	4.59	—+	7.91	7.57	6.58
Av. LWG	5.90	8.01	4.14	5.07	4.67	5.60
Av. HWG	4.83	4.76	3.61	7.47	5.72	6.56
Range	3.65-8.37	3.76-12.71	0.63-5.94	0.48-8.81	3.00-7.57	3.61-8.64
Lot Average	5.3	6.2	3.9	6.1	5.2	6.0
Over-all av. LWG			5.56			
Over-all av. HWG			5.50			

[a]LWG = Low winter-grain subclass (4 lb/head/day).

[b]HWG = High winter-grain subclass (8 lb/head/day).

*Blank indicates no value for steer that died during experiment.

+Blank indicates no value for liver lost in packing house.

may need a comment. Lot 11 was expected to have more storage than lot 8, but since the average weights of the animals in lot 11 were higher than in lot 8, it may be presumed that more carotene was used for growth in Lot 11.

DISCUSSION

Vitamin A and Beef Production

In the final analysis, the success of a beef production operation is determined by the market value of the carcass produced. For the beef animal, the salient characteristics that determine the profitability of the operation are finished weight, dressing percentage and grade, on the credit side, and the cost of feed and labor as well as the interest on the invested capital, on the debit side.

Grade is determined to a large extent by age, marbling and rib eye area, and to some extent by the back-fat thickness. Other things being equal, dressing percentage is influenced, to a large extent, by the back-fat thickness. Finished weight, on the other hand, is determined by the gaining ability of the animal, or specifically, the average daily gains.

Of these three characteristics, grade, dressing percentage, and finished weight, it may be understood that for a given breed and under similar conditions, the latter aspect (finished weight or average daily gains) would respond more to the techniques of the nutritionist. Also, since the final money value is obtained by multiplying these three factors (Total price of beef carcass = total live weight x dressing % x grade (price)) any improvement made in the average daily gains has far-reaching consequences, especially if it is not accompanied by unfavorable regression on the other two factors.

The results indicate that under these experimental conditions (cf. Table 11) the addition of supplemental vitamin A to a sorghum-grain/corn-silage fattening ration does promote a significant increase in average daily gain. There was also an indication that the rate of gain was increased further when the level of silage was raised. It also appears that the basis of the advantage of the high-silage ration over the low-silage ration was not the extra quantity of carotene, but to something else, presumably the bulk or mineral content, or just an unclassified rumen factor. A comparison of the average daily gains of lots 7 and 10 with lot 8, and lot 9 with lot 11 in Table 11, and with the corresponding average 'total vitamin A' intake in Table 4 or Table 22, may substantiate the point. It may be recalled that the animals in the low-silage group were constantly chewing the woodwork of the fence, even though bone meal and salt were always available in the pens.

The highest average daily gains occurred in lot 12 where the average daily consumption of silage was 15.8 lbs, which along with the alfalfa in the pellets and the added 30,000 I.U. of vitamin A provided an estimated intake of about 48,000 I.U. of 'total vitamin A'.

Richardson and Smith (1964) obtained optimum average daily gains of 2.76 lbs from two-year old steers fed for 154 days on similar silage-grain rations which provided 41,000 I.U. 'total vitamin A'. Their ration contained 22 lbs of sorghum silage which analyzed 2.0 mg of carotene per pound as against 2.8 mg/lb found in the corn silage used in this experiment.

Klosterman _et al_. (1964) reported the carotene content of a well-eared corn silage as 3.24 mg/lb on dry matter basis. Feeding this silage to 500 lb steer calves in a fattening program at the rate of 22.5 lbs per head per day, these workers obtained average daily gains of 2.36 lbs over a period of 182 days. When the diet was supplemented with 20,000 I.U. of vitamin A, the gains increased to 2.42 lbs.

Calculations from the figures of Klosterman et al. (1964) (assuming about 30 per cent dry matter in the silage) shows that the silage contained about 10,000 I.U. of potential vitamin A and hence a total daily consumption of about 30,000 I.U. of 'total vitamin A'. These animals were given stilbestrol which may have improved gains 10 to 20 per cent, according to the National Research Council (1963). However, they did not feed antibiotics which Richardson and Smith (1964) noted were responsible for increasing weight gains from about 2.5 to the 2.76 lbs as stated before.

Perry et al. (1962) obtained average daily gains of 2.52 lbs from 470 lb calves treated with stilbestrol and fed for 256 days on a high concentrate ration containing 30,000 I.U. of vitamin A of which 10,000 units were provided by 10 per cent sun-cured alfalfa pellets. When the 10 per cent alfalfa was replaced with extra ground corn cob, the addition of 30,000 I.U. of vitamin A to the ration produced only 2.39 lbs average daily gains.

Probably the sun-cured alfalfa was used to provide extra vitamins D, E and K which have been shown somehow to spare vitamin A (Kohlmeier and Burroughs, 1962; Holts et al., 1961). But if this assumption is true, then the excess levels of vitamin A in the corn cob ration should have resulted in increased rather than decreased gains. Since the two rations contained approximately the same amount of crude fiber, the difference in the quality of the roughage appears to be a factor. Quality of alfalfa is a rather loose expression but it only serves to show that not enough is known about it.

In the experiment by Perry et al. (1962) higher average daily feed consumption was obtained with the rations containing alfalfa rather than the corn cob rations (20.6 lbs versus 19.0 lbs), and the feed conversion efficiencies based upon 100 lbs gain were 816 and 858 lbs of feed, respectively. Other workers in vitamin A nutrition have reported similar results: some have noticed increased total consumption of diets supplemented with vitamin A, while others report of increased feed conversion rates, or both (Davis et al., 1963; Kohlmeier and Burroughs, 1962; Klosterman et al., 1964).

In any case, whenever increased gains of animals are reported, one is fairly safe to assume that one of these factors was operative—either increased feed intake or better feed conversion. Also, where animals consume the same amount of a feed, it is the feed conversion ability that should determine the differences in rates of gain. In short, any factor that affects the normal function of the digestive tract in general, or the rumen of the bovine in particular, is likely to affect the rates of gain in response to a given nutrient.

The results of this experiment as described before and summarized in Tables 12 and 13, showed that although lot 12 in the high silage group consumed as much grain as lot 9 in the low silage group, yet lot 12 utilized the feed more efficiently than lot 9 and consequently attained heavier final weight. Also, among lots 10, 11, and 12 in the high silage group, the rate of grain consumption and efficiency of conversion, as well as the final weights attained, increased with increased level of vitamin A in the diet.

When these results of feed consumption and feed efficiency are compared with the findings of other workers cited above, there appears to be an indication that vitamin A supplement in rations does improve the animals' appetite. But as an animal begins to eat more grain on a limited-roughage diet the concentrate/roughage ratio is upset and the ani al begins to search for roughage, and may then chew the fence posts! If the situation is not corrected, the digestive and absorptive system of the animal may eventually be upset and the animal may reduce feed intake. But where the animal's appetite has been primed with vitamin A in the diet it will continue to eat more but the feed conversion will be lowered because the digestive and absorptive mechanisms are impaired.

By this kind of reasoning one could explain the difference in the average rates of gain between lots 12 and 9, and the lack of apparent disparity between lots 7 and 8. Whereas lot 7 might not have had increased appetite to eat too much because of apparently insufficient vitamin A, lot 8 might have eaten more but converted relatively less because of an encumbered digestive system. The death of one animal from lot 8 due to non-parasitic gastro-enteritis may be quite relevant to this speculation.

The function of a good roughage in vitamin A-supplemented rations may then seem quite apparent. At present it is the cheapest source of vitamin A, and in sufficient quantity, it will maintain proper rumen function. The animal will eat more grain, convert it more efficiently and thus grow faster.

Snapp and Neumann (1962) quote a Nebraska experiment in which a ration of 2 to 3 parts of corn to one part of alfalfa hay gave the most satisfactory results in fattening yearlings or steer calves, since it reportedly increased the consumption of total digestible nutrients.

Although the rations in this experiment were slightly off this ratio, especially in the low-silage group, it may be remembered that on a limited-roughage ration, the level of grain intake is dependent upon the level of roughage consumption.

Experiments by Richardson et al. (1956) showed that for fattening heifers a concentrate/roughage ratio of 5:1 resulted in more rapid weight gains than either one-to-one or 3:1 ratios. On the other hand, digestion trials showed that the 3;1 ratio gave the highest results of total digestible nutrients.

Pope et al. (1957) used a mixed group of heifer and steer calves in similar studies. It was noted that there was no real difference among the ratios compared. The ratios of concentrate-to-roughage ranged from 35:65 to 80:20.

After a more extensive review, Riggs (1958) came to the conclusion that energy in the ration has a satiating effect, and so when animals are fed rations in which the concentrate and roughage are thoroughly mixed, the animals would eat more of the ration containing the higher levels of roughage, but the intake of total digestible nutrients would be practically the same for the groups compared.

Carcass Characteristics

If it is granted that increasing the vitamin A content of a fattening diet containing a liberal quantity of good quality roughage and grain would cause the animal to eat more and utilize the feed more efficiently, then the consequences upon carcass characteristics should be apparent. For a growing animal the increased intake of total digestible nutrients would result in rapid growth, a point which was illustrated fairly well in this experiment when the animals receiving 8 lbs of grain in the winter gained faster than those receiving 4 lbs of grain. Hammes *et al.* (1964) also have some relevant comparisons on this point.

For a mature animal, the increased intake of TDN will result in the deposition of fat in the adipose tissue, particularly in the subcutaneous tissue (back-fat), intraperitoneal tissues (caul fat), perirenal tissue (kidney fat) and intramuscular tissue (marbling). Since fat synthesis is an expensive physiological process in terms of the TDN expended per the equivalent of weight gain, fat animals will begin to show low feed conversion efficiency when they are carried for too long on a fattening program, a point which is well illustrated by the performance of lot 12 during September in terms of average daily gains and feed efficiency, (Tables 11 and 13).

Dressing Percentage and Back-fat Thickness. Statistical analysis showed only slight differences among the dressing percentages of the lots. According to previous discussions one should expect more striking differences in dressing percentage among the lots, but as Butler *et al.* (1962) have pointed out, heavy Hereford steers as contrasted with Angus steers, waste much of their total weight as offal. In other words, the caul and kidney fats of the fatter steers would lower the dressing percentage. Also, by allowing a common 2 per cent cooler shrink for all lots, it is expected that the fatter carcasses would be penalized more than they deserve.

As pointed out before there were no significant differences among the group means of back-fat thickness. This could be a breed characteristic (Shelby, et al. 1955).

Rib-eye Area and Grade. Again, there were no significant differences in the rib-eye areas of the lots. The small individual differences, in fact, tended to favor those on low levels of 'total vitamin A', and this also seemed to be the trend in grades, which may be understandable since the rib-eye area, instead of marbling, would be more important in determining the grade of animals of about the same age and grown under similar conditions. It was actually difficult for the inexperienced eye to detect any differences in the grades as one inspected the carcasses in the cooler.

Weichenthal et al. (1963), Perry et al., (1962), Klosterman et al., (1963) and Richardson and Smith (1964) have all been unable to determine any significant differences in the carcass characteristics as a result of feeding vitamin A.

Vitamin A Adequacy of the Diet

Table 22 summarizes some of the salient points needed in this discussion.

The primary objective of this experiment was to determine the levels of supplemental vitamin A and silage that should be combined so as to secure

Table 22. Relation between vitamin A or carotene in diet or liver, and performance of fattening steers. (A summary from previous tables)

	Low-silage Group			High-silage Group		
		Lot			Lot	
Description	7	8	9	10	11	12
Daily average intake:						
Silage, lbs	9.0	8.9	9.0	14.3	13.6	15.8
Silage carotene, mg	25.20	24.92	25.20	40.04	38.08	44.24
Vit. A equivalent, I.U.[a]	10080	9968	10080	16016	15232	17696
Supplement, lbs	1.5	1.5	1.5	1.5	1.5	1.5
Supplement, carotene, mg[b]	7.12	13.40	6.75	7.13	13.35	6.75
Vit. A equivalent, I.U.	2848	5360	2700	2852	5360	2700
Total Vit. A from carotene	12928	15328	12780	18868	20592	20396
Preformed Vit. A, I.U.	0	13650	27802	0	13650	27802
Total Vit. A., I.U.	12928	28978	40582	18868	34242	48198
Performance:						
Liver Vit. A., I.U./gm	0.77	16.03	30.06	0.91	14.87	34.36
Liver Vit. A, mcg/gm	0.23	4.81	9.08	0.27	4.46	10.31
Liver carotenes, mcg/gm	1.06	1.31	0.77	1.25	1.11	1.21
Av. daily gains, lbs	1.85	1.83	1.92	1.84	1.97	2.15

Average daily gains: Lot 12 > Lots 11 and 9 > Lots 10, 8 and 7.

[a] Carotene estimated as beta-carotene. Assumed 1mg beta carotene = 400 I.U. vitamin A.

[b] Assumed all carotene due to 0.45 lb alfalfa in supplement.

optimum weight gains or performance in general. A secondary objective was to determine how the level of liver vitamin A storage at the time of slaughter reflected on the weight gains and hence the vitamin A adequacy of the diet. This is a different approach from that of Jordan et al. (1963) who estimated the vitamin A adequacy of the diet by considering the rate of depletion of the vitamin from liver and plasma stores, and, incidentally, produced vitamin A deficiency symptoms on a diet of corn silage supplying a daily average intake of 175 mg of carotene (equivalent to 700,000 I.U. of vitamin A) when the liver levels of vitamin A stores fell below 3 mcg/gm of liver.

Klosterman et al. (1963) in an attempt to verify the report of Jordan et al. (1963) used levels of blood plasma vitamin as an index of liver stores. No relationship between the rate of depletion of plasma vitamin A and the rate of weight gains was obtained, but it may be remembered from the evidences cited in the literature review that plasma levels of vitamin A are inadequate as the only index of vitamin A sufficiency. More complete and useful information would have been secured if they had used the liver biopsy technique to study the rate of depletion of the liver stores. However, with a ration containing 25 lbs of poor corn silage that supplied about 10,000 I.U. of vitamin A equivalent of carotene, the addition of 20,000 I.U. of preformed vitamin A caused an increase in the average daily gains of steers from 2.22 lbs to 2.38 lbs. The authors reported slightly untoward reactions in the lots without vitamin A but it was supposed that these were not due to a deficiency of vitamin A.

Richardson et al. (1964) fed a ration containing 22 lbs of sorghum silage with 2.0 mg of carotene per lb. (equivalent to 17,600 I.U. vitamin A) and supplemented with 10,000 I.U. of vitamin A either as carotene from alfalfa meal or crystalline vitamin A. The total intake was thus 27,000 I.U. of vitamin A. The authors found no relation between liver stores of vitamin A at the time of slaughter, and the rate of gain. But there was an indication that those animals that gained faster tended to have lower stores of liver vitamin A. Liver stores of vitamin A ranged from 17 I.U. to 36 I.U. per gram of vitamin A (or 5.2 - 10.9 mcg/gm). There were no vitamin A deficiency symptoms.

According to the report by Jordan et al. (1963) liver vitamin A levels averaging between 2.3 and 2.7 mcg/gm were likely to precipitate vitamin A deficiency symptoms. But it was also reported that increasing the daily vitamin A intake by as much as 32,000 I.U. increased the average vitamin A storage to only 3.3 mcg/gm without any improvement in the average daily gains. However, since some of the experimental animals had been depleted of vitamin A in previous tests, the results cannot be regarded as typical.

Perry et al. (1962) using a poor roughage diet also noted that about 32,000 I.U. of vitamin A gave the optimum rates of gain, and that going beyond this level actually resulted in reduced gains, even though the liver stores of vitamin A were increased proportionately.

The present experiment as reported in Table 22, indicates that very low levels of liver vitamin A stores related to low weight gains, but above an intake of about 28,000 I.U. of vitamin A per day, there was no clear relationship. While lot 12, which made the best gains, stored more liver vitamin A than any of the rest, lot 9 stored more vitamin A than lot 11 (about 2:1 ratio) even though lot 11 gained slightly more than lot 9. The only relevant difference between the two lots was the quantity of silage. Similarly, a comparison between lots 7 and 8 shows that vitamin A storage depended on the vitamin A intake.

The relationship between liver carotenoids and weight gains or total carotene intake was very irregular. It suggests that there was probably no relationship at all.

Comparisons between weight gains and vitamin A storage of the individual steers (Tables 11 and 20) showed that there was no apparent relationship between the levels of storage and the average rates of weight gain.

The unmistakable characteristic of the liver vitamin A stores was the large variation in levels for animals within the same lot. It is difficult to attribute this solely to errors in analytical procedures since all analyses were performed by one person. Probably, some of the animals ate more of the supplement than the others, since the animals were fed on a lot basis.

The incidence of urinary calculi in lot 7 was probably the result of an infection rather than a direct result of vitamin A deficiency, even though it was possible to have an individual animal which had very low reserves of vitaminA inview of the large variations within the lots. However, it would be equally unjustified to apply the result of a rat experiment (cf. Osborne and Mendel, 1917) to cattle, especially where symptoms of vitamin A deficiency are concerned.

SUMMARY

Sixty Hereford steer calves were divided equally into six uniform lots and used in a two-stage, 2^3 factorial experimental design to study the following responses: (1) the effect on average daily gains when a wintering ration is supplemented with 4 or 8 lbs of grain per head per day, (2) the effect of the winter gains on performance during the fattening phase, and (3) the effect of 10 or 20 lbs of silage in the average daily ration, during the fattening phase, on performance when the rations are supplemented with 0, 15,000 or 30,000 I.U. of preformed vitamin A.

Two lots in the high-silage could not consume their allowance of silage during the fattening phase, so the allowances of the other lots were cut down accordingly.

Results of the wintering phase showed that, on the average, the steers in the high-grain group gained about 20 lbs more than those in the low-grain group, but the lot average daily gains of both groups were not statistically different.

The results of the fattening phase showed that, on the average, the steers in the high-silage group were about 22 lbs heavier than those in the low-silage group. Also the average daily gains were significantly greater ($P < 0.05$) in the high-silage group than in the low-silage group, but these gains were not influenced by the winter gains. Rather, there was a distinct increase in gains ($P < 0.01$) when the high level of silage was supplemented with vitamin A. In both groups the lots whose 'total vitamin A' intake were less than about 30,000 I.U. did not differ either in final average weights or in average daily gains.

Grain consumption did not differ significantly, but grain utilization seemed to favor those on high-levels of silage.

There was no clear-cut difference between the two groups in their carcass characteristics, but generally, the low-silage or low 'total vitamin A' groups had a slight advantage over their counterparts, especially in grade and dressing percentage.

Liver stores of vitamin A were highly variable even within the same lot of animals, but generally storage followed the levels of the added preformed vitamin A, rather than the 'total vitamin A' intake. Statistically, the means of the liver vitamin A storage of animals whose average daily rations were supplemented with 30,000 I.U. of vitamin A were significantly greater ($P < 0.01$) than the means of animals fed average daily rations containing 15,000 I.U. of supplemental vitamin A. Except in the highest level of vitamin A intake, there was no indication of a relationship between growth rate and vitamin A stores. Carotenoid stores were equally unpredictable as to levels of storage and growth rates of the animals.

The interpretation of these results were based on a speculation that adequate levels of roughage in the diet of fattening steers permits optimum expression of the effects of supplemental vitamin A.

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LEVELS OF VITAMIN A SUPPLEMENTATION OF A STEER-FATTENING RATION CONTAINING HIGH OR LOW LEVELS OF SILAGE

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Sixty Hereford steer calves were divided equally into six uniform lots and used in a two-stage, 2^3 factorial experimental design to study the following responses: (1) the effect on average daily gains when a wintering ration is supplemented with 4 or 8 lbs of grain per head per day, (2) the effect of the winter gains on performance during the fattening phase, and (3) the effect of 10 or 20 lbs of silage in the average daily ration, during the fattening phase, on performance when the rations are supplemented with 0, 15,000 or 30,000 I.U. of preformed vitamin A.

Two lots in the high-silage could not consume their allowance of silage during the fattening phase, so the allowances of the other lots were cut down accordingly.

Results of the wintering phase showed that, on the average, the steers in the high-grain group gained about 20 lbs more than those in the low-grain group, but the lot average daily gains of both groups were not statistically different.

The results of the fattening phase showed that, on the average, the steers in the high-silage group were about 22 lbs heavier than those in the low-silage group. Also the average daily gains were significantly greater ($P<0.05$) in the high-silage group than in the low-silage group, but these gains were not influenced by the winter gains. Rather, there was a distinct increase in gains ($P<0.01$) when the high level of silage was supplemented with vitamin A. In both groups the lots whose 'total vitamin A' intake was less than about 30,000 I.U. did not differ either in final average weights or in average daily gains.

Grain consumption did not differ significantly, but grain utilization seemed to favor those on high-levels of silage.

There was no clear-cut difference between the two groups in their carcass characteristics, but generally, the low-silage or low 'total vitamin A' groups had a slight advantage over their counterparts, especially in grade and dressing percentage.

Liver stores of vitamin A were highly variable even within the same lot of animals, but generally storage followed the levels of the added preformed vitamin A, rather than the 'total vitamin A' intake. Statistically, the means of the liver vitamin A storage of animals whose average daily rations were supplemented with 30,000 I.U. of vitamin A were significantly greater ($P < 0.01$) than the means of animals fed average daily rations containing 15,000 I.U. of supplemental vitamin A. Except in the highest level of vitamin A intake, there was no indication of a relationship between growth rate and vitamin A stores. Carotenoid stores were equally unpredictable as to levels of storage and growth rates of the animals.

The interpretation of these results were based on a speculation that adequate levels of roughage in the diet of fattening steers permits optimum expression of the effects of supplemental vitamin A.