LEVELS OF VITAMIN A SUPPLEMENTATION OF A STEER FATTENING RATION WITH HIGH AND LOW LEVELS OF ROUGHAGE

by

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INTRODUCTION

Recent widespread use of high concentrate rations for beef cattle has renewed research on vitamin A requirements. The use of high grain rations in the feedlot has resulted from increasing prices of roughage accompanied by lowering of the prices of grain and higher labor costs. Many feedlot operations tend to reduce the amount of roughage to a level as low as possible which will still support adequate rumen function.

Symptoms of vitamin A deficiency have been reported in feedlots coincident to the following conditions: the finishing rations contain high grain and low roughage, corn silage is used as a source of roughage, and during the summer months.

Much research has been done on vitamin A for beef cattle though, because of various factors influencing the utilization of vitamin A and its precursors, many of the findings are in disagreement. Little has been learned, concerning the role of vitamin A in the body; therefore one should exercise care in applying a supplementation of vitamin A in the feedlot since there may be unrecognized factors not yet determined in evaluating the requirements of vitamin A by beef cattle. The committee that revised the 1958 publication on the nutrient requirements of beef cattle changed their recommendation in view of the results of recent research. Undoubtedly further changes will be required as more facts are learned.

This project is a continuation of a study that is being conducted at Kansas State University to determine the beneficial level of supplementation of vitamin A in beef cattle rations. The present study will seek to compare as well as to continue research in this area. This has been achieved through a comparison of the performance of six lots of steers first conditioned to

feedings of either 4 lbs. or 8 lbs. of sorghum grain during the wintering period and then transferred to diets of high or low roughage supplemented with approximately 0, 15,000 or 30,000 IU of vitamin A.

REVIEW OF LITERATURE

Utilization of Vitamin A in the Body

It is widely acknowledged that vitamin A is absorbed from the intestine. Eden's work (1950) showed that vitamin A ester was almost completely hydrolyzed in the intestinal lumen of sheep and calves four hours after administration. Mahadevan et al. (1963 a) suggested that all esters of vitamin A were hydrolyzed whereupon the vitamin A alcohol crossed the cell membrane and inside the cell was re-esterified, preferentially with palmitic acid. Transportation of vitamin A across the cell wall is energy-dependent; sugar and ATP can accelerate the transportation while glucolytic substances inhibit it (Ganguli, 1960). Another study by Mahadevan et al. (1963 b) in which an everted intestinal sac, in vitro, was used, showed that the hydrolytic enzyme was located in the outer surface of the cell whereas the esterifying enzyme was inside the cell. Retinal (vitamin A aldehyde) enters the cell unchanged (Deshmukh et al., 1965) and the reduction is catalyzed by liver alcohol dehydrogenase (Zahman and Olson, 1961). Beta-carotene can form a lipoprotein complex during absorption and penetrates the mitochondrial membrane to reach the beta oxidative enzyme system (Glover, 1960).

Vitamin A ester is transported from the intestine only as a fatty acid ester and goes through the lymphatic system, whereas in the blood, vitamin A alcohol and ester are transported as two separate low density lipoproteins (Ganguli, 1960). Further work of Deshmukh et al. (1964) suggests that the

combination of lipoprotein and vitamin A alcohol represents the normal state in which vitamin A is mobilized for tissue requirements, while the combination of another lipoprotein and vitamin A ester represents a newly absorbed vitamin A.

It has been confirmed that vitamin A ester predominates in the liver with a small amount of vitamin A alcohol always present (Ganguli, 1960). By use of a blocking agent of the reticulo-endothelial system of deficient rats prior to oral administration of vitamin A, Ganguli (1960) found that the blockage caused a nearly 50% reduction in concentration of the ester, with practically no change in the vitamin A alcohol content of the liver. He concluded that it was quite possible that vitamin A ester was stored in the Kupffer cells and the alcohol in the parenchymal cells of the liver. McLaren et al. (1964) also mentioned that vitamin A ester was stored in Kupffer cells.

Thomas and Moore (1952) concluded that when an animal was on a scheduled intake of a diet containing carotene, liver vitamin A was a better indication of vitamin A status than plasma vitamin A and that plasma carotenoids were a better indication than plasma vitamin A.

Rousseau et al. (1956) found that with an increase in vitamin A intake, plasma vitamin A increased at a diminishing rate while liver vitamin A increased at a constant rate. When carotene was fed, plasma carotenoids and vitamin A concentration increased at diminishing rates whereas liver carotenoids and liver vitamin A increased proportionally to the increase in carotene intake. The relationships between the logarithms of vitamin A intake, carotene intake, and vitamin A stored in the liver, were linear. The slope of the line obtained by plotting carotene intake against vitamin A stored in the liver, was greater than that of the line obtained by plotting

vitamin A intake against vitamin A stored in the liver.

The mechanism of carotene's conversion to vitamin A is still not clearly known. There are two hypotheses accepted: (a) central fission and (b) terminal oxidation (Glover, 1960; Harashima, 1964; Dyke, 1965). Glover mentions that no storage took place when carotene was administered parenterally, although beta carotene reached the liver in a measurable amount; therefore, the intestine is the site of conversion. In his experiments with the C^{14} labelled compound, he concluded that when beta carotene was administered orally in arachis oil containing approximately the right amount of vitamin E for the biosynthesis of vitamin A, the carotene was metabolized into small fragments that could enter the metabolic pool, implying an oxidative attack at more than one position in the chain. Harashima (1964) found (in vitro with rat intestine) that the conversion required oxygen. During a semi-anaerobic phase beta-carotene was absorbed by the intestinal sections and during the aerobic phase the reaction took place. From the statistical analysis of the efficiency of conversion under different conditions, he concluded that the conversion occurred by some mechanism other than terminal oxidation and was more in keeping with the concept of central cleavage. One of the intermediate conversion products of beta carotene is retinal (Deshmukh et al., 1965).

Embry et al. (1962) found in work on cattle that 2.5 mg beta carotene appeared equal to 1000 IU vitamin A on the basis of gain and liver storage, but on a plasma basis the former was more efficient. These equivalent values are the same as those given in the National Research Council publication (1958).

It has been reported by Jordan et al. (1960), Smith et al. (1964) and

Durdle (1964) that carotene in corn silage is poorly utilized and increases expenditure of vitamin A. This phenomenon is associated neither with nitrate content nor low biopotency of the carotene in the silage.

The role of vitamin A in the body is little known, except in the visual pigment as reviewed by Dyke (1965). He notes that rods and cones contain a vitamin A aldehyde derivative which before the retinal and a protein are liberated, is bleached on exposure to light in a series of reactions. In cattle vitamin A deficiency symptoms due to inferior feeding were known as "fat sickness" long before the discovery of the vitamin. The blindness symptom in cattle results from the damage to the optic nerve associated with abnormalities in the growth of the bone (Moore, 1960).

Another known function of vitamin A is to maintain the epithelial cells, and the biochemical site of action is within the cell membrane (Lucy and Dingle, 1965).

Muscular incoordination, staggering gait and convulsive seizures are caused by hypovitaminosis A, and may develop as a result of elevation of the pressure of the cerebro spinal fluid. Eaton et al. (1964 a) reported that with 1.05 mcg vitamin A per gram liver, or more pressure of the spinal fluid remained at 74 mm saline and for each 10% decrease in liver vitamin A the pressure rose by 4.5%.

Factors Influencing Metabolism of Vitamin A in Cattle

Since the absorption of carotene and the transportation of vitamin A require lipoproteins, it is easily understandable that protein plays an important role in the metabolism of the vitamin. Vakil et al. (1964) reported that rats deprived of protein but given vitamin A had significantly

lower liver stores of the vitamin. Erwing and Gordon (1963) saw a similar phenomenon with steers. Both hydrolytic and esterifying enzymes, as well as the enzyme that is used for carotene conversion into retinal, are drastically affected by protein intake, presumably because of the loss of enzyme activity as shown in rats by Deshmukh et al. (1964, 1965).

Virginia et al. (1964) stated that the quality of protein is important in the storage of vitamin A in rats. Gallup et al. (1951) saw no adverse effect of dietary urea upon storage of vitamin A in sheep. The research of Smith et al. (1964 b) led to the conclusion that whenever dietary urea is utilized efficiently to meet the body's need of protein, there is no adverse effect of urea upon vitamin A.

Another interaction between protein and vitamin A was reported by Bhattacharya and Esh (1963) from their experiment on rats. They found that vitamin A supplementation slightly reduced loss of weight during protein depletion; conversely, it accelerated the rate of gain in the repletion period. The plasma protein also followed the same trends.

Interrelationships between vitamin A and other fat-soluble vitamins have been studied. Kohlmier et al. (1962) reported that when vitamin E and vitamin K were given along with vitamin A to cattle believed to be low in body stores of vitamin A, a better gain and improved feed conversion resulted than when vitamin A was fed alone. Nelson (1962) obtained an improvement of the performance of steers when ethoxyquin was incorporated with either 0 or 5,000 IU vitamin A but not with higher levels of vitamin A. Roels et al. (1965) found that when a large amount of alpha tocopherol was given to rats, the concentration of vitamin A in the liver was significantly higher than that in the control. On the contrary, Erwing et al. (1963) reported that hepatic

vitamin A stores were reduced significantly by ethoxyquin when no vitamin A was added to dehydrated alfalfa rations. Beeson et al. (1965) stated that a combination of 25,000 IU vitamin A and 50 IU vitamin E gave less response in terms of the rate of gain of cattle and the vitamin A storage than when given individually. Working with germ-free rats, Wastmann et al. (1965) concluded that when vitamin A intake exceeded the optimum level by a factor of 10 or more, an antagonistic effect between vitamin A and vitamin K became apparent; otherwise no effect of vitamin A intake upon vitamin K was demonstrable. Vitamin D had no effect on blood or liver vitamin A and carotene (King et al., 1964).

Effects of combinations of vitamin A and an antibiotic on steers were studied by Richardson et al. (1961, 1964); the combination of vitamin A and 70 mg aureomycin produced larger gains than dehydrated alfalfa or vitamin A alone. Dyer et al. (1957), using 5 mg oxytetracycline per pound of ration, and Perry et al. (1962 b), using 80 mg chlortetracycline daily, obtained the same results. However, Perry et al. (1962 b) mentioned further that the chlortetracycline depressed the growth when it was fed without vitamin A supplementation. Feeding an antibiotic did not influence the amount of vitamin in the blood or in the liver. The same workers observed that diethylstilbesterol caused no significant change in the daily gain with an unsupplemented vitamin A ration but gave a highly significant increase in gain when vitamin A was included. There was, however, no correlation between gain and amount of the diethylstilbesterol fed with the vitamin supplementation. Erwing et al. (1956) found that vitamin A storage in the liver was not affected by feeding chlortetracycline or diethylstilbesterol.

Addition of fat did not significantly increase the hepatic storage of

vitamin A (Dyer et al., 1957; Rasmussen et al., 1964). Chapman et al. (1964) and Anthony et al. (1965) reported that vitamin A caused an increase in the deposition of copper in the liver of ruminants. The effect of thyro-active substances on vitamin A was seen by Jordan et al. (1963). During hot weather, supplementation with 32,000 IU vitamin A failed to improve the blood and liver vitamin A unless 20 mg triiodo-thyramin was administered weekly.

Microorganisms in the rumen liquor may destroy part of the ingested vitamin A. As shown by Klatte et al. (1964), 36.1% of the vitamin A fed to steers and sheep was destroyed by ruminal fluid. Variations of pH in the ruminal fluid were not closely related to the varying vitamin destruction. Destruction in the abomasal fluid was similar to that in the ruminal fluid. Keating et al. (1964) observed in their in vitro experiment that the destruction of vitamin A by rumen liquor obtained from steers on a high roughage ration was significantly greater than the destruction by rumen liquor obtained from steers receiving a high grain ration. It seems that the time spent in the rumen and other compartments would be the major factor affecting the destruction.

Other factors that influence the utilization of vitamin A that are probably receiving more attention now are nitrates and nitrites. Keating et al. (1964) reported that addition of 1% potassium nitrate to the ration had little effect on the in vitro destruction of vitamin A and that the in vitro addition of a high level of nitrate to the rumen liquor adversely affected the retention of vitamin A with concentrate ration only. Nitrite additions, however, adversely affected the retention of both high and low roughage rations. Beta carotene levels appeared to be little affected other than by nitrite addition to the rumen liquor in the case of steers fed a low

roughage ration. In this instance the nitrite additions reduced significantly the retention of carotene. Hale et al. (1961) claimed that high energy rations could reduce the harmful effect of nitrate. Workers cited by Goodrich et al. (1964) have related nitrate consumption to impaired carotene utilization and vitamin A nutrition in animals. From his experiment with sheep fed rations containing 2.5% and 3.0% added sodium nitrate, he concluded that there was no effect of nitrate on plasma vitamin A levels; however, lower stores of liver vitamin A were found. Only a small amount of methemoglobin was found in the blood. Weichental et al. (1963) reported that addition of 1% sodium nitrate to the ration reduced performance of fattening cattle but had no effect on plasma and liver carotenoids and vitamin A. Smith et al. (1962) claimed that methemoglobin increased when ruminant animals were fed a ration to which nitrate was added. The findings of Wallace et al. (1964) and Davidson et al. (1963, 1964) were somewhat different. Using Hereford calves and yearlings that had been depleted as to liver vitamin A content, Wallace et al. observed that daily gain and feed consumption were not significantly influenced by nitrate level in the diets. Calcium nitrate, up to 1.2% in a diet containing 20% or 40% concentrate rations, had no apparent effect on carotene or vitamin A storage in the liver or plasma and no effect on methemoglobin. Wallace et al. (1964) mentioned also that animals fed a high concentrate ration gained faster than those fed a low one. Davidson and Seo (1963) using an artificial rumen, reported that although about 25% of the carotene was destroyed by microorganisms present in the rumen fluid, the process was not faster in animals fed nitrate than the controls. Further addition of nitrate did not increase the destruction of carotene. There was no indication, in ewes, that nitrate interfered with the utilization of

carotene in forages, although the amount of nitrate eaten was lethal in some cases. Cline et al. (1963) also reported no effect of potassium nitrate on either rate of gain or storage of vitamin A in the liver of fattening lambs. A similar result was obtained with beef cattle by Newland and Deans (1964). Roberts and Sall (1963) reported that the addition of potassium nitrate to the abomasum where the pH was below 4 resulted in rapid destruction of vitamin A, but in the rumen where the pH was above 6, relatively little vitamin A was destroyed. Dietary nitrate did not enhance vitamin A destruction in sheep. From this experiment an assumption can be drawn that if the dietary nitrate does not reach the abomasum, little effect of nitrate upon carotene or vitamin A is to be observed.

Vitamin A in Beef Cattle Rations

Guilbert et al. (1937, 1940) found that the requirement of vitamin A for mammalian species was 25-30 mcg of carotene or 6-8 mcg of vitamin A per kg. of body weight but that the intake of vitamin A necessary for significant storage of the vitamin in the liver was 3 to 5 times greater than the intake for normal growth and prevention of deficiency symptoms. With carotene, it was 5 to 10 times greater. A level of 1.4 to 1.7 mg of carotene per 100 lbs. body weight is recommended in the National Research Council publication (1958) and this is based on the work of Guilbert et al. (1951).

Rousseau et al. (1954) and Eaton et al. (1964 b) reported that the minimum amounts of carotene and vitamin A required by male Holstein calves (220 lbs., 12 weeks of age) to maintain a plasma value of 10 mcg % vitamin A, were 31 and 3.8 mcg, respectively. To achieve a liver concentration of 0.6 mcg per gram, the requirements were 30 and 3 mcg, respectively. For

maintenance of cerebro-spinal fluid pressure, the requirements were 48 and 6.4 mcg per pound of body weight, respectively. There are differences between breeds in carotene requirement as reported by Boyer et al. (1942) and Braun (1945).

Embry et al. (1962), using rations supplemented with 5 different levels of vitamin A ranging from 1,000 to 5,000 IU per 100 lbs. body weight or with 2.5 mg carotene from dehydrated alfalfa with or without 1,000 or 2,000 IU vitamin A, concluded that 2,000 IU per 100 lbs. body weight appeared to be a safe practical level for fattening cattle. This conclusion is in agreement with that derived from the work of Perry et al. (1962). They observed that 10,000 IU vitamin A supplementation with 10% sun cured alfalfa pellets or 20,000 IU vitamin A without the alfalfa gave significantly more gain, but higher levels had no further effect. The feed consumption up to these levels was also improved.

The initial storage of the vitamin in the liver is an important factor on the requirement of vitamin A supplementation of fattening ration, as indicated by Roberts and Phillips (1963).

Byers and Kendall (1964) maintained steers for 2.5 to 3 years under levels of vitamin A or carotene equivalent to 30,000 IU daily. The animals appeared normal even though normal blood carotene and vitamin A were accompanied by low vitamin A status in the liver.

Fattening steers can meet their requirement of vitamin A from meadow hay containing carotene of 20 mg per pound (Wallace et al., 1964) or corn silage containing 3.24 mg per pound on the dry matter basis (Klosterman et al., 1964). No significant improvement in performance or carcass value was found by Klosterman with the addition of 20,000 IU vitamin A.

Brethour (1964) indicated that average daily gain, daily dry matter intake, and daily dry matter consumed per pound gain during a 178-day trial were not affected by adding 20,000 IU vitamin A; however, addition of the vitamin A significantly increased the backfat thickness. When silage consumption was reduced to 5 lbs. daily, addition of vitamin A improved the carcass grade. Feeding 20,000 IU vitamin A daily for 165 days had no effect on gain and performance, but further feeding reduced the marbling score and led to lower carcass grade.

Perry et al. (1964) saw no significant difference on the rate of gains between 20,000 IU vitamin A fed daily and an initial injection of 4 million IU vitamin A.

Vitamin A and its precursors are subjected to oxidation when added to rations under practical conditions. This may be overcome by adding vitamin A in gelatinized granules. This gelatin coated vitamin A premix is the most stable form available at present for animal feeding stuffs (Olsen et al., 1959). Authors cited by Olsen et al. (1959) found that a synthetic vitamin A premix would remain stable for at least six months. However, when this premix was added to a practical chick ration, approximately 30% potency was lost within 3 months.

Pelleting tests with seven different vitamin A premixes revealed that the potency retained after 90 days storage ranged from 35% to 73% with an average of 60% (Wornick, 1959). A loss of 30% in 154 days with pelleted supplements was reported by Richardson et al. (1964).

MATERIALS AND METHODS

Wintering Phase

Sixty Hereford steer calves, averaging 440 pounds each, were obtained from Warner's Ranch in Rice County, Kansas. They were randomized by weight into 6 lots of 10 animals each in such a way that the average weights of the lots obtained from two consecutive weighings during the two last days preceding the start of the experiment were the same.

The lots were numbered from 7 to 12 according to the serial numbers of pens allocated to them.

The wintering phase lasted for 112 days, from November 13, 1964 to March 5, 1965. All animals were fed sorghum silage ad libitum, soybean oil meal at a rate of a pound per head daily and coarsely ground sorghum grain. About 4 lbs of grain per head daily was fed to the steers in lots 7, 8 and 9. These lots were designated as low winter-grain group (LWG). Lots 10, 11 and 12 which received about 8 lbs. grain per head daily were designated as the high winter-grain group (HWG). Salt and mineral mix were provided free-choice. The animals obtained sufficient drinking water from self-operating taps. The steers were fed twice daily between 7 and 8 a.m. and between 4 and 5 p.m. The protein supplement was fed in the morning with half of the allowance of silage and grain. The rest of the allowance was fed in the evening.

The animals were weighed every 28 days and at the end of this phase they were weighed twice on two consecutive days to obtain the average final weight of the wintering phase.

Fattening Phase

This phase lasted for 213 days, from March 6, 1965 to October 4, 1965. The animals from the wintering phase were regrouped into 6 lots of 10 animals each. Each lot contained 5 steers from the high winter-grain group and from the low winter-grain group. The weight of each lot was adjusted in such a way as to assure that each lot had almost the same average weight.

The steers received sorghum grain, sorghum silage and 1.5 lbs. of specific supplements. The grain was fed ad libitum for all lots. The initial amount was 8.3 lbs. per head daily and this was increased by 0.5 lb. per day until it reached the maximum amount that could be eaten as indicated by the bunk being cleaned. The grain consumed was increased as the allowance of silage was gradually decreased until finally at the beginning of April, lots 7, 8 and 9 received 16 lbs. of silage per head daily while lots 10, 11 and 12 received 8 lbs. Lots 7 and 10 received a supplement containing 20,000 IU vitamin A palmitate per pound (supplement #68); lots 8 and 11 received one containing 10,000 IU vitamin A palmitate per pound (supplement #67); and lots 9 and 12 received a non vitamin A supplement (supplement #66).

After the experiment had been in progress for 111 days, the silage was used up and prairie hay was used as a substitute for it. From then until the experiment terminated, lots 7, 8 and 9 received 4 lbs. prairie hay per head daily, while lots 10, 11 and 12 received 2 lbs. At the end of the experiment all feeds left were weighed back.

Tables number 1, 2 and 3 summarize the important data on the feeds.

The experiment was terminated on October 4. The average of the weights of each animal taken on the last two consecutive days was recorded as the

animal's final or feed lot weight. Eighteen hours elapsed between the terminal weighing and slaughter. During that period the steers were given only prairie hay and water. All animals in each lot were weighed together just before they were slaughtered and the weights were reported as market weights. The animals were slaughtered in a commercial packing plant (Armour Co., Emporia, Kansas).

The carcass data, viz., hot carcass weight, estimated percentage kidney knob fat, back-fat thickness, tracing of rib eye area at 12th rib, degree of marbling and carcass grade were taken on each individual animal. Samples for vitamin A analysis were taken from the small lobe of each liver.

Chemical Analysis

Silage samples were collected directly from the silo in quart size sampling jars. Each sample was air dried at 100°C for 24 hours in a hot air blast oven and used for proximate analysis following the procedures as described by A.O.A.C. (1960). The same procedure was used for the proximate analysis of grain, hay and supplements.

Samples for carotene and vitamin A determinations were taken every 4 weeks on the day when the steers were weighed. Samples were frozen until analyzed. Carotene content in the silage and the hay was determined using the A.O.A.C. method (1960). A carotene standard (85% beta and 15% alpha) was obtained from General Biochemicals.[1] The standard curve of carotene is presented in Fig. 1. A standard for vitamin A was obtained from the U.S.P.

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[1]General Biochemicals Inc., Chagrin Falls, Ohio.

vitamin A reference solution.[1] This material contained 30 mg vitamin A alcohol per gram of solvent (cottonseed oil). The standard curve of vitamin A is presented in Fig. 2.

An Evelyn photoelectric colorimeter was used for the determination of carotene and vitamin A content in the supplement by methods which followed closely the procedures of A.O.A.C. (1960).

A slight modification of the extraction procedure was made to obtain a better recovery. The extraction with hexane was made 4 times instead of 3 times. For the first extraction, a volume of hexane twice the weight of the sample was used. Hexane equivalent to approximately 2/3 of the weight of the sample was used for subsequent extractions. The extract was decanted through a small pledget of cotton; this filter was rinsed with hexane to assure complete transfer of the vitamin. A recovery of 97% was obtained by this method.

Sometimes vitamin A eluates, after being chromatographed, were quite yellow in color. This was due to the elution of cryptoxanthine and similar pigments along with vitamin A alcohol. Therefore a correction factor had to be applied. A suitable correction factor was obtained by saponification and extraction of yellow corn (A.O.A.C., 1960). The extract was then chromatographed and the 15% acetone in hexane eluate was saved. A serial dilution of the eluate covering the range of percentage transmittance between 60 and 100 was made and read at 440 millimicrons to determine carotenoid concentration. The aliquot of a corresponding dilution was treated as vitamin A, using Carr-Price reagent, and read at 620 millimicrons. The data obtained from the measurement at 620 millimicrons were compared with those of the vitamin A

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[1]United States Pharmacopeia, Washington, D. C.

standard and plotted against the value for carotenoids of the corresponding dilutions. The slope was used as the correction factor (Fig. 3).

The recovery values of vitamin A content in the supplements obtained from the chemical analysis were 83.8% and 76.5% for the supplements 67 and 68, respectively, of the original amounts added (10,000 IU per pound for supplement 67 and 20,000 IU per pound for supplement 68). Undoubtedly, the loss was because of the sampling errors due to the nonuniformity of the distribution of vitamin A in the pellets and the loss of the vitamin A potency during storage as was shown by Wornick (1959), Olsen et al. (1959) and Richardson et al. (1964).

Liver samples were frozen in dry ice immediately after collection, and kept below 0°C until ready to be analyzed by a modification of the method used by Heaton et al. (1957).

To a 5-10 g sample of liver, 10 ml of 50% (w/v) potassium hydroxide and 10 ml of 95% ethyl alcohol were added. The mixture was heated gently under reflux for 30 minutes. It was then extracted twice with dry ether in two separatory funnels, once with 50 ml and once with 40 ml. The extract was washed free of alkali and alcohol and then dried with anhydrous sodium sulfate. The yellow color (carotenoids) of the solution was read at 440 millimicrons and vitamin A was determined by use of Carr-Price reagent. To check on the ether used for freedom from peroxides a procedure as follows was made: a known amount of vitamin A standard was dissolved in the ether, and let settle for 2 hours (the length of time required for an extraction of vitamin A in the liver). The recovery of the vitamin A was then determined by use of Carr-Price reagent. Since the recovery was 100%, no further treatment of the ether was necessary.

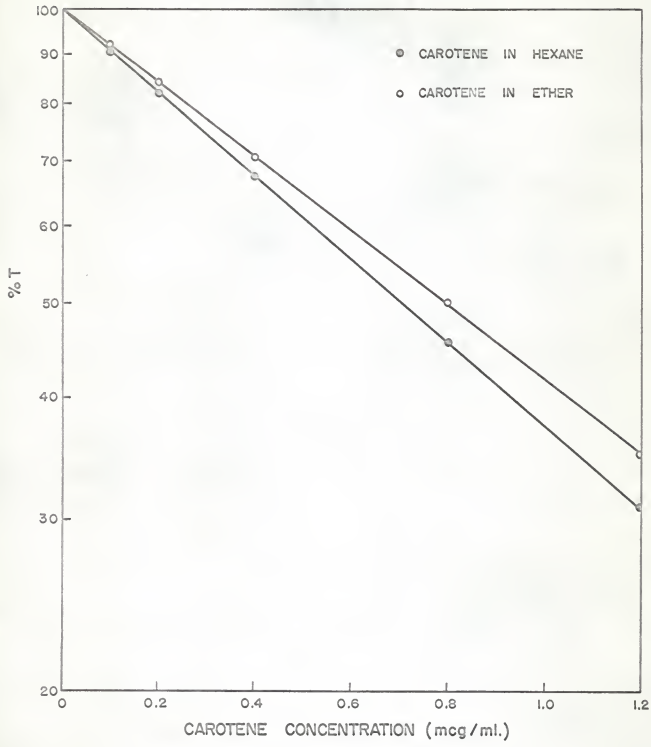

Fig. 1 Standard curve of carotene (85% beta and 15% alpha)

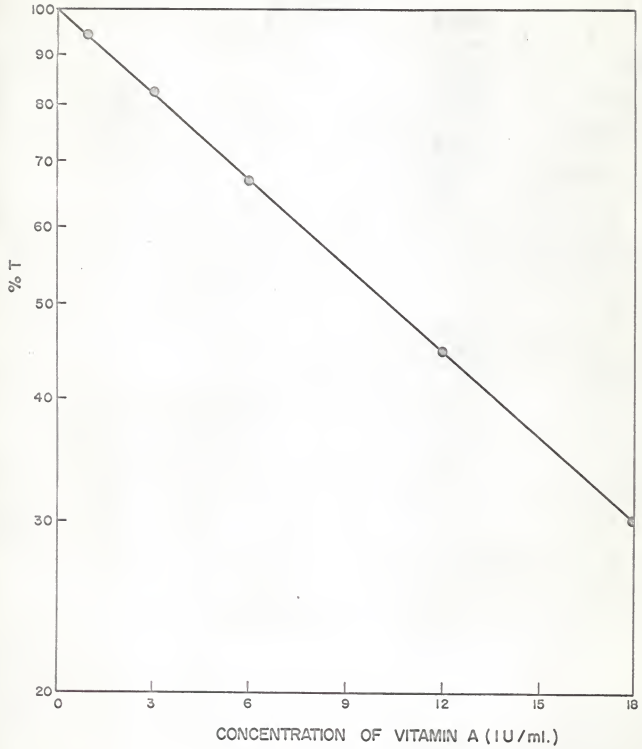

Fig. 2 Standard curve of vitamin A

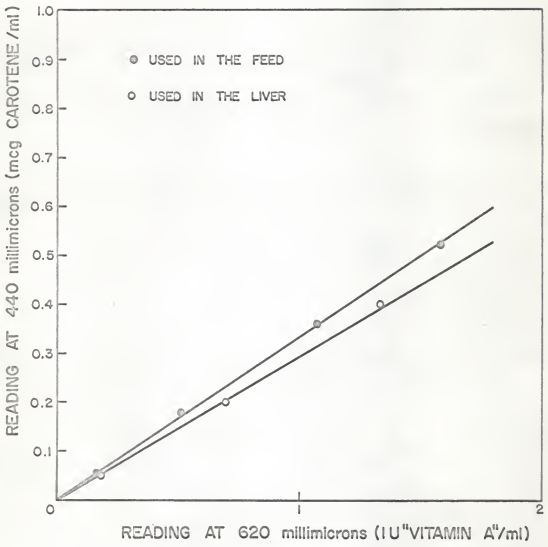

Fig. 3 Correction factor for yellow pigments in the reading of vitamin A.

Purified carotene (85% beta and 15% alpha) in ether solution was used as a standard (Fig. 1). The correction factor for the interference of yellow pigments at a wavelength of 620 millimicrons was determined using the same procedure as for the correction factor in feed. In this case serial dilutions of 85% beta and 15% alpha carotene were substituted for an extract obtained from saponification and extraction of yellow corn. The correction factor is also shown in Fig. 3.

A typical example of the use of the correction factor is given below using the analysis made on March 5 on Supplement 67. After the eluate had been obtained from the alumina column and made to a volume of 100 ml, 10 ml was read at 440 millimicrons. This gave a reading of 65% T which is equal to 0.44 mcg carotene/ ml (see Fig. 1). Now, applying this as a correction, this amount of carotenoids will change the photometer reading of vitamin equivalent to 1.32 IU/ ml (see Fig. 3).

The sample was then evaporated under vacuum and dissolved in 1.0 ml chloroform. Nine ml of Carr-Price reagent was added. The blue color was read at 620 millimicrons. A reading of 47% T was obtained which is equal to 11.4 IU vitamin A/ ml (see Fig. 2). This amount of vitamin A (11.4 IU/ ml) minus the correction due to the addition of Carr-Price Reagent in the presence of carotenoids (1.32 IU vitamin A equivalent/ ml) is the actual value of vitamin A present.

Table 1. Proximate analyses of sorghum silage, hay, sorghum grain and supplements (averages of two samples each).

Feedstuff	Moist.	Prot.	Ether Ex.	Fiber	Ash	N.F.E.
	%	%	%	%	%	%
Silage	66.21	2.26	0.84	8.09	2.42	20.18
Prairie hay	7.01	6.29	3.13	34.29	6.31	42.97
Sorghum grain	10.70	8.52	3.93	1.93	0.77	74.15
Supplement #66	9.62	33.13	1.71	11.73	8.77	35.04
Supplement #67	9.83	32.63	1.98	13.05	8.83	33.68
Supplement #68	9.46	31.37	1.63	13.51	9.40	34.36

Table 2. Composition of supplements per ton.

Soybean oil meal	1200 lbs.
Dehydrated alfalfa	604 lbs.
Molasses	88 lbs.
Ground limestone	88 lbs.
Aurofac 10	10 lbs.
Supplement no. 66: Soybean oil meal added up to	2000 lbs.
Supplement no. 67: Vitamin A (10,000 IU/g)	2000 g
Soybean oil meal added up to	2000 lbs.
Supplement no. 68: Vitamin A (10,000 IU/g)	4000 g
Soybean oil meal added up to	2000 lbs.

Ingredients were supplied and pelleting done by Feed and Flour Milling Department, K. S. U.

Table 3. Periodical analyses of carotene and vitamin A contents in silage, hay and supplements.

Samples Taken, date	Silage Carotene mg/lb.	Prairie Hay Carotene mg/lb.	Suppl. 66 Carotene mg/lb.	Suppl. 67		Suppl. 68	
				Car. mg/lb.	Vit. A IU/lb.	Car. mg/lb.	Vit. A IU/lb.
March 5	1.74	-	6.36	6.37	12,145	6.41	25,328
April 2	2.22	-	7.00	3.36	7,018	6.18	17,339
April 30	1.73	-	8.78	6.24	8,963	5.90	13,523
June 25	-	19.35	7.15	5.51	8,785	5.32	15,260
July 23	-	22.43	8.12	4.21	11,042	5.26	14,227
Aug. 20	-	22.72	9.27	7.09	5,329	7.30	11,393
Sept. 17	-	22.91	7.83	5.35	5,375	5.20	9,890
Average	1.90	21.85	7.79	5.45	8,380	5.95	15,280

RESULTS

Wintering Phase

All sixty animals went through the wintering phase very well and there were no serious problems. Information concerned with this phase is summarized in Table 4.

Visually, all animals looked healthy, and they were not different in appearance at the beginning of the experiment. At the end of the wintering phase, the 30 animals which received an average of 7.5 lbs. of grain per head daily looked larger than the other 30 animals that received 4.2 lbs. daily.

The total gain and average daily gain in pounds of each individual animal are shown in Table 5. Statistical analysis of these data indicated that the steers fed a high grain ration gained significantly more than those fed a low grain ration ($P < 0.01$).

Animals receiving the higher grain ration made better gains but cost more to produce a 100-pound gain at current feed prices.

The wintering period was designed as a preparation for the fattening phase. Further discussion of this period will therefore be presented later with closely related data for the fattening phase.

Fattening Phase

During this period, one animal in lot 12 foundered. It was removed from the experiment on July 18. Some animals suffered foot rot but healed after some time; only one animal in lot 12 was permanently crippled. No vitamin A deficiency symptoms were seen among the animals.

A summary of the pertinent results obtained during the fattening period,

Table 4. Summary of the results obtained during the wintering phase, November 13, 1964 to March 5, 1965.

Lot no.	7	8	9	10	11	12
No. steers per lot	10	10	10	10	10	10
Av. initial wt., lbs.	441.0	440.5	440.5	441.5	441.0	441.5
Av. final wt., lbs.	620.5	617.5	622.5	633.0	638.5	642.5
Av. daily gain, lbs.	1.60	1.58	1.63	1.71	1.76	1.79
Av. daily ration, lbs.						
Sorghum silage	23.4	23.2	23.2	17.7	17.7	17.9
Sorghum grain	4.2	4.2	4.2	7.5	7.5	7.5
Soybean oil meal	1.0	1.0	1.0	1.0	1.0	1.0
Feed per cwt. gain, lbs.						
Sorghum silage	1461.0	1469.0	1428.6	1035.8	1004.3	990.5
Sorghum grain	263.9	267.8	260.2	440.2	426.8	419.4
Soybean oil meal	67.4	63.3	61.5	58.5	56.7	55.7
Feed cost per cwt. gain, $	13.61	13.78	13.40	15.31	14.84	14.59

Table 5. Total wintering gain and average daily gain of each animal during the wintering phase, in lbs.

Lot no. 7		Lot no. 8		Lot no. 9		Lot no. 10		Lot no. 11		Lot no. 12	
Total gain	A.D.G.	Total gain	A.D.G.	Total gain	A.D.G.	Total gain	A.D.G.	Total gain	A.D.G.	Total gain	A.D.G.
205	1.83	165	1.47	175	1.56	190	1.70	200	1.79	260	2.32
185	1.65	165	1.47	180	1.61	160	1.43	180	1.61	205	1.83
140	1.25	210	1.88	200	1.79	200	1.79	145	1.29	180	1.61
170	1.52	165	1.47	155	1.38	210	1.88	200	1.79	165	1.47
160	1.43	160	1.43	175	1.56	205	1.83	210	1.88	195	1.74
190	1.70	180	1.61	215	1.92	210	1.88	220	1.96	210	1.89
185	1.65	185	1.65	170	1.52	210	1.88	230	2.05	190	1.70
175	1.56	180	1.61	190	1.70	165	1.47	195	1.74	235	2.10
185	1.65	175	1.56	175	1.56	175	1.56	195	1.74	175	1.56
200	1.79	150	1.34	185	1.65	190	1.70	200	1.79	195	1.74
Average 179.5	1.60	177	1.58	182	1.63	191.5	1.71	197.5	1.76	201	1.79

Average total gain of the low winter-grain lots: 179.5 lbs.
Average daily gain of the low winter-grain lots: 1.63
Average total gain of the high winter-grain lots: 196.5 lbs.**
Average daily gain of the high winter-grain lots: 1.75**

including carcass characteristics and liver storage of vitamin A and carotenoids, is given in Table 6.

The subsequent paragraphs describe in detail some of the results summarized in the table.

Rate of gain. No visual abnormalities were observed in the animals during the fattening phase. The disparity of weight which was found to result in the wintering phase was not apparent at the end of the fattening phase. The low winter-grain group caught up from their retarded position and even gained a little better in this phase than did the animals in the high winter-grain group.

The average weights of the steers in each lot at every 28 day weighing period and their average daily gains over the periods are shown in Table 7. In the 28-day period after the roughage was changed from silage to hay, the rate of gain of the animals was slightly depressed; there was a compensating gain in the following period. Therefore it is evident that an adaptation to the new kind of feed influenced the rate of gain.

The total gain and the average daily gain of each animal are shown in Tables 8a and 8b. Statistical analysis of the data in this table indicated that a supplementation of 22,920 IU vitamin A per head daily gave a significantly higher gain than was obtained at the other levels of supplementation. This influence was also reflected in the total gain calculated from the initial weight to the finished weight at the end of the experiment as shown in Tables 9a and 9b.

The wintering treatment, levels of roughage and their interactions did not have any significant influence on either fattening or total gain. On the contrary, the average total gain of the high winter-grain group was

Table 6. Summary of results of fattening phase.

Groups	High-roughage Group			Low-roughage Group		
Lot No.	7	8	9	10	11	12
No. of steers	10	10	10	10	10	9
Av. initial wt. per steer, lbs.	626	630	629	628	630	630
Av. final wt. per steer, lbs.	1101	1077	1083	1143	1100	1084
Av. daily gain, lbs.	2.22	2.10	2.13	2.42	2.21	2.13
Vit. A added daily, IU	22,920	12,570	0	22,920	12,570	0
Av. daily ration, lbs.						
Supplement	1.5	1.5	1.5	1.5	1.5	1.5
Sorghum grain	16.0	14.7	15.9	17.6	17.4	15.3
Silage (Mar. 6-June 25)	16.3	16.4	16.6	9.5	9.5	9.3
Hay (June 25-Oct. 4)	4	4	4	2	2	2.2
Feed per cwt. gain, lbs.						
Supplement	67.7	71.5	70.4	62.0	68.0	70.4
Sorghum grain	736.8	761.9	748.1	722.0	787.1	718.5
Silage	361.8	406.9	406.4	205.8	223.5	228.6
Hay	85.6	90.4	89.0	39.2	43.0	49.4
Feed cost per cwt. gain, $	19.02	18.66	19.36	17.30	18.82	17.72
Shrinkage to market, %	5.1	5.1	5.7	5.5	4.1	3.9
Av. hot carcass wt., less 2%, lbs.	640.6	633.1	639.1	627.3	648.3	646.1
Dressing %, market wt.	61.5	62	62.3	62.3	61.9	62.0
Av. fat thickness 12th rib, in.	0.66	0.74	0.74	0.74	0.66	0.76
Av. size rib-eye, sq. in.	10.44	10.72	10.50	11.26	10.79	10.97
Carcass grades:						
Prime	-	-	2	-	-	-
Top Choice	-	1	1	1	2	1
Av. Choice	4	5	-	1	2	6
Low Choice	6	4	7	8	4	2
Good	-	-	-	-	2	-
Vit. A per gram liver, IU	49.87	22.48	9.96	28.56	13.05	3.93
Carotenoids per gram liver, mcg	2.09	2.73	2.50	1.42	1.39	1.95

Table 7. The rate of gain of steers and their corresponding average daily gains during the fattening phase, on a lot basis, for every 28 day weighing period, in lbs. (calculated by dividing the lot average gain over 28 day period by 28, except for the last period of 17 days which was divided by 17).

Period	Lot 7		Lot 8		Lot 9		Lot 10		Lot 11		Lot 12	
	Gain	A.D.G.	Gain	A.D.G.	Gain	A.D.G.	Gain	A.D.G.	Gain	A.D.G.	Gain	A.D.G.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3/5 -4/2	83.5	2.98	73.5	2.63	74	2.64	73.5	2.63	58.5	2.09	74.5	2.66
4/2 -4/30	159	2.70	150	2.73	154.5	2.88	160.5	3.11	142.5	3.00	153.0	2.88
4/30-5/28	233	2.64	212.5	2.23	224	2.48	231	2.52	206.5	2.29	207.5	1.95
5/28-6/25	268.5	1.27	260	1.69	262	1.36	295.5	2.30	254	1.70	243	1.29
*6/25-7/23	317	1.73	297	1.32	301	1.39	332.5	1.32	283.5	1.05	283.3	1.44
7/23-8/20	379.5	2.23	362	2.32	371	2.50	413	2.88	373	3.20	362.2	2.82
8/20-9/17	424.5	1.61	417.5	1.98	413	1.50	459	1.64	417.5	1.59	403.9	1.49
9/17-10/4	472	2.79	447	1.74	454	2.41	515	3.29	470	3.09	453.9	2.94

*Hay was substituted for silage on 6/25.

Table 8a. The total gain of each animal during the fattening phase, in lbs.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	435	445	435	485	510	485
	500	460	455	515	395	485
	475	465	465	495	475	410
	500	455	445	485	490	445
	500	425	410	625	470	525
HWG	485	420	460	500	370	395
	465	475	425	505	520	450
	510	420	515	475	450	470
	550	435	515	525	505	420
	300	470	405	540	515	-
Av. LWG	482	450	442	521	468	470
Av. HWG	462	444	464	509	472	434
Av. Lot	472	447	453	515	470	454

Over-all av., LWG	472
Over-all av., HWG	464
Over-all av., 22,920 IU vitamin A suppl.	493.5*
Over-all av., 12,570 IU vitamin A suppl.	458.4
Over-all av., 0 IU vitamin A suppl.	452.5
Over-all av., high roughage group	457
Over-all av., low roughage group	479

*Significantly greater under 5% level of rejection than the other levels of supplementation with vitamin A.

Table 8b. The average daily gain of each steer during the fattening period, in lbs.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	2.04	2.09	2.04	2.28	2.39	2.28
	2.35	2.16	2.14	2.42	1.85	2.28
	2.23	2.18	2.23	2.32	2.23	1.92
	2.35	2.14	2.09	2.28	2.30	2.09
	2.35	2.00	1.92	2.93	2.21	2.46
HWG	2.28	1.97	2.16	2.35	1.74	1.85
	2.18	2.23	2.00	2.37	2.44	2.11
	2.39	1.97	2.42	2.23	2.11	2.21
	2.58	2.05	2.42	2.46	2.37	1.97
	1.41	2.21	1.90	2.54	2.42	-
Av. LWG	2.26	2.10	2.08	2.45	2.20	2.21
Av. HWG	2.17	2.09	2.18	2.39	2.22	2.04
Av. Lot	2.22	2.10	2.13	2.42	2.22	2.13

Table 9a. The total gain of each animal, calculated by subtracting the initial weight from the final weight, in lbs.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	610	630	600	690	700	625
	685	630	665	675	570	670
	660	625	655	675	630	585
	690	670	645	665	665	615
	700	600	575	790	655	710
HWG	685	600	670	700	575	655
	675	695	635	710	750	660
	690	610	680	620	645	645
	745	600	750	725	665	595
	495	660	605	735	725	-
Av. LWG	669	631	628	699	644	641
Av. HWG	658	633	668	698	672	639
Av. Lot	663	632	648	698	658	640

Over-all av., LWG	652
Over-all av., HWG	661
Over-all av., 22,920 IU vit. A supplementation	681*
Over-all av., 12,570 IU vit. A supplementation	645
Over-all av., 0 IU vit. A supplementation	644
Over-all av., high roughage group	648
Over-all av., low roughage group	665.5

*Significantly greater under 5% level of rejection than the other levels of supplementation with vitamin A.

Table 9b. The average daily gain of each animal calculated by subtracting the initial weight from the final weight, in lbs.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	1.88	1.94	1.85	2.12	2.15	1.92
	2.11	1.94	2.05	2.08	1.75	2.06
	2.03	1.92	2.02	2.08	1.94	1.80
	2.12	2.06	1.98	2.05	2.05	1.89
	2.15	1.85	1.77	2.43	2.02	2.18
HWG	2.11	1.85	2.06	2.15	1.77	2.02
	2.08	2.14	1.95	2.18	2.31	2.03
	2.12	1.88	2.09	1.91	1.98	2.03
	2.29	1.85	2.31	2.23	2.05	1.98
	1.52	2.03	1.86	2.26	2.23	-
Av. LWG	2.06	1.94	1.93	2.14	1.98	1.97
Av. HWG	2.02	1.95	2.05	2.15	2.07	1.97
Av. lot	2.04	1.95	1.99	2.14	2.03	1.97

slightly higher than that of the low winter-grain group as shown by comparison of data in Tables 8 and 9.

Although the level of roughage did not significantly influence the fattening gain, the low roughage group showed a considerably greater gain than the high roughage group. The highest average daily gain of the fattening period (2.42 lbs.) and the highest average daily gain calculated from the initial weight to the finished weight (2.14 lbs.) was found in lot 10, where the low level roughage ration was supplemented with the highest level of vitamin A supplementation.

Feed consumption. The average daily consumption of grain, silage, hay and supplement, per head in each lot is shown in Table 6. Since the amount of silage, hay and supplement offered was strictly controlled, there was no considerable difference in the amount of intake of these feeds.

On Table 10a data are shown on the average monthly rate of grain consumption by the steers. These intakes are presented as individual intakes as well as consumption by lot. The corresponding grain efficiencies are shown in Table 10b. The efficiency is reported as the pounds of grain consumed per pound of weight gain. There was no difference in the monthly rate of grain intake within each lot. Obviously the animals that received the low roughage ration consumed more grain than those that received the high roughage ration.

When the grain consumed by the animals in lot 7 and lot 10 is compared with the grain consumed by the animals in lots 8 and 11 and also with that consumed by the steers in lot 9 and lot 12, it can be seen that increasing the level of vitamin A supplementation tended to increase the feed consumption. However, the combinations of the corresponding values of calculated feed efficiency, 7.30; 7.45 and 7.34, respectively, for supplementation

Table 10a. Monthly rate of grain consumption, in lbs., by lots during the fattening phase, calculated to an average individual basis, lbs.

Period	High roughage group			Low roughage group		
	Lot			Lot		
	7	8	9	10	11	12
3/5 -4/2	341.5	338.5	349.5	359.5	359.5	359.5
4/2 -4/30	454.5	400.3	427.0	479.2	479.2	452.3
4/30-5/28	490.2	412.4	444.0	528.0	528.0	460.7
5/28-6/25	499.5	412.5	448.0	545.0	495.0	416.5
6/25-7/23	509.5	442.5	470.5	515.0	480.0	415.3
7/23-8/20	455.8	454.8	504.0	505.0	490.0	456.0
8/20-9/17	441.4	433.7	472.5	495.0	475.0	433.3
9/17-10/4	285.3	242.9	280.8	291.7	292.8	265.5
Total	3477.7	3137.6	3396.3	3718.4	3699.5	3269.7
Av. daily	16.3	14.7	15.9	17.6	17.4	15.3

Average daily consumption, high roughage group	15.6
Low roughage group	16.8
Of lots supplemented 22,920 IU vitamin A	16.95
Of lots supplemented 12,570 IU vitamin A	16.05
Of lots supplemented 0 IU vitamin A	15.10

Table 10b. Efficiency of grain utilization during fattening phase.

Period	High roughage group			Low roughage group		
	Lot			Lot		
	7	8	9	10	11	12
3/5 -4/2	4.09	4.61	4.72	4.89	6.15	4.72
4/2 -4/30	6.02	5.23	5.30	5.51	5.70	5.61
4/30-5/28	6.62	6.60	6.39	7.49	8.25	10.11
5/28-6/25	14.07	8.68	11.79	8.45	10.42	12.29
6/25-7/23	10.51	11.96	12.06	13.92	16.27	11.50
7/23-8/20	7.29	7.00	7.20	6.27	5.47	5.75
8/20-9/17	9.81	7.81	11.25	10.76	10.67	10.40
9/17-10/4	6.01	8.23	6.85	5.21	5.58	5.36
Average	7.37	7.02	7.48	7.22	7.87	7.19

of 22,920 IU, 12,570 IU and 0 IU vitamin A, indicate that the highest supplementation of vitamin A had little effect on feed efficiency.

Contrary to what was found for the wintering phase for grain, in the fattening phase the low roughage ration produced more economical gains than the high roughage one. The supplementation of 22,920 IU vitamin A to the low roughage ration produced the lowest cost of gain.

Shrinkage to market. The market weight and the per cent shrinkage of the animals during transportation followed by a night in the packing company pens, was 1044.5 lbs., 5.1%; 1022.5 lbs., 5.1%; and 1022.5 lbs., 5.7% for lots 7, 8 and 9 respectively, while for lots 10, 11 and 12 the values were 1080.0 lbs., 5.5%; 1054.5 lbs., 4.1%; and 1041.7 lbs., 3.9% respectively. The average market weights of animals in lots 7, 8 and 9 were significantly smaller ($P < 0.05$) than of those in lots 10, 11 and 12. In other words, the animals receiving a high roughage ration shrank more than the ones receiving a low roughage ration.

Carcass Characteristics

Hot carcass weight. The hot carcass weight of each individual animal is shown in Table 11. Because the percent shrinkage of the animals in lots 7, 8 and 9 was greater than that of steers in lots 10, 11 and 12, statistical analysis of the data showed that the animals in the low roughage group had a significantly ($P < 0.05$) greater average carcass weight than those in the high roughage group. Even though supplementation with 22,920 IU vitamin A produced a considerably heavier carcass than the other levels of supplementation, the difference was not significant under a reasonable rejection level. The animals in the high winter-grain group had a slightly heavier average

Table 11. Hot carcass weight, in lbs.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	618	630	618	692	690	651
	644	641	668	660	636	678
	660	646	631	661	638	612
	656	660	650	668	661	648
	694	641	605	761	661	711
HWG	676	643	666	706	612	673
	639	661	631	704	696	656
	681	640	691	628	653	681
	706	636	736	682	674	625
	563	662	626	689	695	-
Av. LWG	654	644	634	690	657	660
Av. HWG	653	648	670	682	666	659
Av. Lot	654	646	652	686	662	659

Over-all av., LWG	657
Over-all av., HWG	662
Over-all av., 22,920 IU vit. A supplementation	670
Over-all av., 12,570 IU vit. A supplementation	654
Over-all av., 0 IU vit. A supplementation	658
Over-all av., high roughage group	651
Over-all av., low roughage group	669*

*Significantly ($P < 0.05$) greater than av., high roughage group.

carcass weight than those in the low wintering group but, again, the difference was not significant. The interactions among the levels of roughage, levels of vitamin A and the difference in the wintering treatments showed no differences.

Carcass dressing percentage. The data on calculated dressing percentage are reported in Table 12. The percentages were calculated from:

$$\frac{\text{hot carcass weight} - 2\%}{\text{market weight}} \times 100$$

The 2% correction was for estimated cooler shrink; hot carcass weight minus 2% represented chilled carcass weight.

The dressing percentages were uniform throughout all lots. They were not influenced by the different levels of roughage, vitamin and wintering treatment or their interaction. It was found that the animals in the lots that did not receive any vitamin A supplementation had a higher dressing percentage than the animals in any other lots.

Rib eye area. A summary of the measurements of rib eye areas obtained by tracing and determination of area by use of a planimeter, is given in Table 13. There were no significant differences among the means or the subclass means. However there was a tendency toward a lot X subclass interaction. The animals wintered on the low level grain and fattened on the high level vitamin A supplementation (22,920 IU) had a higher mean rib eye area than those from the other treatments. The animals receiving a low level roughage ration in the fattening phase had a slightly higher mean rib eye area than the ones receiving a high level roughage ration.

Back-fat thickness. Back-fat thickness of the animals was measured perpendicular to the length of the rib eye muscle at one-third the distance

Table 12. Carcass dressing percentage, on the market weight basis.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	61.4	61.1	61.7	62.2	61.6	62.4
	61.5	62.1	63.1	62.0	63.1	61.7
	62.3	62.6	59.3	62.2	61.2	60.9
	60.0	60.8	63.4	62.4	61.4	62.3
	62.3	63.1	62.5	63.1	62.2	62.5
HWG	62.3	62.9	62.6	63.4	61.6	61.8
	58.4	60.1	61.6	62.7	59.5	61.8
	62.8	61.8	63.8	62.3	60.9	64.0
	61.0	62.8	64.6	61.2	61.8	61.6
	62.5	62.1	62.9	60.8	61.5	-
Av. LWG	61.5	61.9	62.0	62.5	61.9	62.0
Av. HWG	61.4	62.1	63.1	62.1	61.9	62.1
Av. lot	61.5	62.0	62.3	62.3	61.9	62.0

Over-all av., LWG	62.0
Over-all av., HWG	62.0
Over-all av., 22,920 IU vit. A supplementation	61.9
Over-all av., 12,570 IU vit. A supplementation	61.7
Over-all av., 0 IU vit. A supplementation	62.3
Over-all av., high roughage group	62.0
Over-all av., low roughage group	61.9

Table 13. Rib eye area, at 12th rib, measured in sq. inches.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	10.40	10.28	11.49	10.84	11.86	9.77
	12.38	9.81	9.11	10.62	10.20	10.41
	10.88	10.41	10.15	12.39	10.68	10.99
	11.68	10.83	9.93	12.58	10.95	8.96
	9.49	11.43	12.44	13.10	10.51	12.53
HWG	8.34	11.12	10.12	9.14	9.50	13.12
	9.20	10.00	9.86	9.92	11.04	11.34
	9.50	10.42	11.18	12.24	12.08	10.18
	11.42	11.68	11.15	10.60	10.60	11.01
	11.05	11.21	9.66	11.14	10.45	-
Av. LWG	10.97	10.55	10.65	11.91	10.84	10.53
Av. HWG	9.44	10.89	10.35	10.61	10.73	11.41
Av. lot	10.44	10.72	10.50	11.26	10.79	10.97

Over-all av., LWG	10.91
Over-all av., HWG	10.66
Over-all av., 22,920 IU vit. A supplementation	10.85
Over-all av., 12,570 IU vit. A supplementation	10.75
Over-all av., 0 IU vit. A supplementation	10.74
Over-all av., high roughage group	10.56
Over-all av., low roughage group	11.01

from its inner end. The results of the measurements are presented in Table 14. Statistically, there were no significant differences among the means of the different treatments or their interactions. The steers not receiving vitamin A supplementation had slightly thicker fat than those receiving vitamin A.

Estimated percentages of kidney knob, degree of marbling and grade. The estimated kidney knob in percentage of the carcass is given in Table 15; Table 16 is a summary of the degree of marbling and the grade of each individual animal. Statistically, there was no difference among the lots in the kidney knob, the degree of marbling and the grade, or the lot X subclass interactions. The interesting thing about the grade is that the animals receiving preformed vitamin A were graded a little lower than those receiving no preformed vitamin A. The high roughage feeding in the wintering phase as well as in the fattening phase tended to produce steers that graded better than those receiving the low roughage feeding.

Liver Storage of Vitamin A and Carotenoids

The estimated average daily intake of vitamin A and carotene in the various lots is summarized in Table 17. The hepatic storage of vitamin A is reported in Table 18 as concentration of vitamin A per gram liver tissue.

Examination of the data in Table 18 indicate that there was a large variation among the animals within a lot with respect to the vitamin A concentration in the liver. However, statistical analysis indicated that the storage of vitamin A in the liver of lots 7 and 10 was significantly greater than of lots 8 and 11 ($P < 0.01$) and both were significantly ($P < 0.01$) greater than of lots 9 and 12. The animals in lots 7, 8 and 9 had a

Table 14. Back-fat thickness, at 12th rib, in inches.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	1.0	0.4	0.4	0.3	0.7	0.8
	0.5	0.8	1.0	0.5	0.5	1.1
	0.7	1.1	0.7	0.8	0.6	0.7
	0.4	0.9	0.7	0.6	0.5	0.6
	0.8	0.8	0.7	0.6	0.5	0.6
HWG	0.9	1.0	0.8	0.9	0.5	0.7
	0.5	1.0	0.5	0.7	0.6	0.6
	0.6	0.6	0.8	0.8	0.8	0.8
	0.7	0.7	0.7	0.8	0.4	0.4
	0.5	0.6	1.0	1.2	1.1	-
Av. LWG	0.68	0.80	0.72	0.60	0.64	0.88
Av. HWG	0.64	0.68	0.76	0.88	0.68	0.63
Av. lot	0.66	0.74	0.74	0.74	0.75	0.76

Over-all av., LWG	0.72
Over-all av., HWG	0.71
Over-all av., 22,920 IU vit. A supplementation	0.70
Over-all av., 12,570 IU vit. A supplementation	0.70
Over-all av., 0 IU vit. A supplementation	0.75
Over-all av., high roughage group	0.71
Over-all av., low roughage group	0.72

Table 15. Estimated kidney knob, % of carcass.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	3.0	3.0	2.5	2.5	3.0	3.0
	3.5	3.0	3.0	3.0	3.0	3.0
	3.5	3.0	3.0	2.5	3.0	2.5
	3.0	2.5	3.5	3.0	3.0	3.0
	3.5	3.0	3.0	3.5	2.5	3.0
HWG	3.0	3.0	3.0	3.0	3.0	3.5
	3.0	3.0	3.0	3.0	3.0	3.0
	3.0	2.5	3.0	3.0	2.5	3.0
	3.0	3.0	2.5	3.5	3.0	2.0
	2.0	3.0	3.0	3.0	3.0	-
Av. LWG	3.3	2.9	3.0	2.9	2.9	2.9
Av. HWG	2.8	2.9	2.9	3.1	2.9	2.9
Av. lot	3.1	2.9	3.0	3.0	2.9	2.9

Over-all av., LWG	3.0
Over-all av., HWG	2.9
Over-all av., 22,920 IU vit. A supplementation	3.0
Over-all av., 12,570 IU vit. A supplementation	2.9
Over-all av., 0 IU vit. A supplementation	2.9
Over-all av., high roughage group	3.0
Over-all av., low roughage group	2.9

Table 16. Degree of marbling (D.m.) and grade (G.).

Group	High roughage group						Low roughage group					
Lot	7		8		9		10		11		12	
	D.m.[a]	G.[b]	D.m.[a]	G.[b]	D.m.[a]	G.[b]	D.m.[a]	G.[b]	D.m.[a]	G.[b]	D.m.[a]	G.[b]
LWG	6	5	6	5	7	4	7	4	5	6	6	5
	6	5	5	6	7	4	7	4	5	6	6	5
	7	4	7	5	5	6	7	4	5	6	6	5
	7	4	7	5	5	6	7	4	6	4	5	6
	7	4	7	4	7	4	7	4	9	2	7	4
HWG	7	4	7	4	7	4	6	5	7	4	6	5
	6	5	7	4	5	7	7	4	7	4	6	5
	6	5	6	5	7	4	7	4	7	4	6	5
	7	4	7	4	4	7	7	4	9	2	7	4
	7	4	6	5	7	4	7	4	6	5	-	-
Av. LWG	6.6	4.4	6.4	5.0	6.6	4.4	6.6	4.4	6.2	4.6	6.0	5.0
Av. HWG	6.6	4.4	6.6	4.4	6.0	5.2	6.8	4.2	7.2	3.8	6.2	4.8
Av. lot	6.6	4.4	6.5	4.7	6.3	4.8	6.7	4.3	6.7	4.2	6.1	4.9

	Degree of marbling	Grade
Over-all av., LWG	6.4	4.6
Over-all av., HWG	6.6	4.5
Over-all av., 22,920 IU vit. A supplementation	6.7	4.4
Over-all av., 12,570 IU vit. A supplementation	6.6	4.5
Over-all av., 0 IU vit. A supplementation	6.2	4.9
Over-all av., high roughage group	6.5	4.6
Over-all av., low roughage group	6.5	4.5

[a]1, Very abundant; 2, Abundant; 3, Moderately abundant; 4, Slightly abundant; 5, Moderate; 6, Modest; 7, Small amount; 8, Slight amount; 9, Trace; 10, Practically void.

[b]1, Low good; 2, Av. good; 3, Top good; 4, Low choice; 5, Av. choice; 6, Top choice; 7, Low prime; 8, Av. prime; 9, Top prime.

Table 17. Estimated daily intake of carotene and vitamin A by lots.

Ingredient	Intake per head daily by lot					
	7	8	9	10	11	12
Silage, lbs.	16.3	14.7	15.9	9.5	9.5	9.3
Hay, lbs.	4	4	4	2	2	2.2
Supplement, lbs.	1.5	1.5	1.5	1.5	1.5	1.5
Preformed vit. A, IU[a]	22,920	12,570	0	22,920	12,570	0
Vit. A equivalent of carotene, IU[b]	26,577	28,338	27,794	15,641	15,607	17,585
Total vit. A intake, IU	49,497	38,908	27,794	38,561	28,177	17,585

[a]Value obtained by multiplying average vitamin A content per pound of the corresponding supplement, as tabulated in Table 3, by 1.5.

[b]Value obtained from the average daily intake of carotene from silage, hay and the corresponding supplement, in mg, multiplied by the factor, 400, to convert carotene to vitamin A.

Table 18. Liver vitamin A storage IU per gram liver tissue.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	73.73	31.13	5.41	11.29	12.75	10.39
	13.89	23.46	10.04	34.85	9.34	3.80
	57.55	23.82	4.91	73.15	11.95	3.68
	49.36	37.08	9.90	21.29	14.39	2.36
	77.98	6.06	33.54	18.42	9.38	1.69
HWG	48.22	34.89	2.65	35.94	12.75	5.37
	35.79	22.81	1.61	13.66	14.50	4.11
	95.28	6.42	10.59	36.50	9.48	2.95
	26.27	21.06	8.34	17.43	5.25	1.01
	20.64	18.10	12.22	23.08	7.58	-
Av. LWG	54.49	24.31	12.84	31.80	11.56	4.38
Av. HWG	45.24	20.65	7.08	25.32	14.54	3.54
Av. Lot	49.87	22.48	9.96	28.56	13.05	3.93

Over-all av., LWG	23.23
Over-all av., HWG	19.37
Over-all av., 22,920 IU vit. A supplementation	39.21**
Over-all av., 12,750 IU vit. A supplementation	17.77**
Over-all av., 0 IU vit. A supplementation	6.92**
Over-all av., high roughage group	27.44**
Over-all av., low roughage group	15.17**

** Significant under $P < 0.01$.

significantly ($P < 0.01$) higher vitamin A concentration in the liver compared with the animals in lots 10, 11 and 12. This suggests that the higher the preformed vitamin A supplementation and the higher the level of roughage fed, the higher the resulting hepatic vitamin A concentration.

The influence of the wintering treatment was not significant even though the mean of the hepatic vitamin A concentration of the animals wintered on the low grain ration was higher than that of those on the high grain ration. There was no significant difference in the interaction of the treatments.

Data on the estimated total carotenoids stored per gram of liver tissue are summarized in Table 19.

Liver carotenoids are an unidentified mixture which may include alpha-, beta-, and gamma-carotene, xanthophyll, lycopene and other color pigments, which may or may not have potential value to the animal as vitamin A precursors. Therefore the evaluation of the carotenoids as a source of vitamin A was difficult since no separation of the pigments was made.

Statistically, the higher roughage ration resulted in a significantly higher carotenoid content in the liver ($P < 0.01$). No significant influence of wintering phase could be seen. Although the supplementation of vitamin A had no significant effect on the carotenoid concentration, there was a strong tendency for the higher level vitamin A supplementations to reduce the storage of carotenoids in liver. No significant influence of interactions among treatments was found.

Table 19. Liver carotenoid concentration, mg per gram liver tissue.

Description	High roughage group			Low roughage group		
Lot no.	7	8	9	10	11	12
LWG	1.95	2.63	2.42	1.40	1.05	2.03
	1.26	2.12	1.81	1.29	1.51	1.61
	2.57	3.13	2.43	1.74	1.56	2.51
	2.90	3.20	2.99	1.16	0.97	1.01
	1.51	2.60	3.07	0.89	1.69	2.02
HWG	1.89	3.70	1.79	1.12	1.90	1.53
	3.56	2.33	1.69	2.03	1.74	2.00
	2.03	3.13	1.84	1.38	1.17	1.58
	1.93	2.64	1.84	2.03	1.46	3.29
	1.36	1.74	3.61	1.15	0.89	-
Av. LWG	2.06	2.73	2.54	1.28	1.36	1.83
Av. HWG	2.15	2.72	2.45	1.54	1.43	2.10
Av. lot	2.09	2.73	2.50	1.41	1.39	1.97

Over-all av., LWG	1.97
Over-all av., HWG	2.07
Over-all av., 22,920 IU vit. A supplementation	1.75
Over-all av., 12,570 IU vit. A supplementation	2.06
Over-all av., 0 IU vit. A supplementation	2.23
Over-all av., high roughage group	2.44**
Over-all av., low roughage group	1.59**

**Significant under $P < 0.01$.

DISCUSSION

Weight gain. Examination of the results of the work reported here indicated that 22,920 IU vitamin A supplementation per head daily resulted in a significantly better gain when compared with 12,570 IU or 0 IU vitamin A supplementation.

Embry et al. (1962) recommended 2000 IU vitamin A per 100 lbs. body weight. Perry et al. (1962) reported that an optimal level of vitamin A supplementation to a ration containing 18.0 mg carotene was 20,000 IU per head daily and that higher levels of supplementation did not result in further improvement. King et al. (1964) succeeded in improving the average daily gain of beef cattle by a supplementation of 20,000 IU vitamin A only when the corn silage feeding was limited to 5 lbs. or 15 lbs. per day; high level of silage tended to reduce the average daily gains.

Without considering the amount of carotene in the ration, the results of this study were quite in agreement with the findings of the workers cited above. However, when the total vitamin A intake was considered, the amount of vitamin A necessary to produce a significantly heavier gain was somewhat greater than expected from previous research. The reason for this situation was probably the difference in stress borne by the animals. Stress plays an important role in the requirement of vitamin A, as shown by Chapman et al. (1964) who found that the improving action of vitamin A supplementation of 25,000 IU or 50,000 IU was visible only in the winter and not in the summer. Richardson et al. (1964) obtained no difference in average daily gains of steers fed silage-grain rations which contained calculated daily vitamin A intakes ranging from 30,000 IU to 45,000 IU supplied by dehydrated alfalfa, preformed vitamin A or both. Roberts and Philips (1963) reported that

supplementation with vitamin A up to 72,000 IU did not increase gain, but supplementation with 66.3 mg of carotene did result in a better gain than that given by supplementation with 25,000 IU vitamin A. The initial vitamin A status also influences the result of vitamin A supplementation, as reported by Roberts and Phillips (1963).

Lots that did not receive vitamin A (lots 9 and 12) made the same average daily gains and showed only a slight difference in the total gain. The calculated total vitamin A intake of lot 8 was about the same as that of lot 10, and so were the intakes of lot 9 and lot 11, but the gain of both lots of the high roughage group were lower than those of the corresponding lots of the low roughage group. This indicates that vitamin A supplementation had more influence on the low roughage group than on the high one. However, statistical analysis of the data failed to give an indication, under a reasonable rejection level, that level of roughage and its interactions influence the average daily gain.

The beneficial effect of a high grain ration was shown in the wintering phase ($P < 0.01$) and a slightly better gain was obtained in the fattening phase in the low roughage group. Richardson et al. (1956) reported that a concentrate-to-roughage ratio of 5:1 resulted in a more rapid gain than a ratio of 3:1 or 1:1.

A comparison of results of this study with those of previous parallel research (Buamah, 1964) shows agreement in some cases. Buamah (1964) reported that a supplementation of 30,000 IU in both groups and a supplementation of 15,000 IU vitamin A to the high roughage group significantly increased the weight gain. In the present study the lot that received the high roughage ration supplemented with 12,570 IU failed to show a increased

gain, apparently because of the unsatisfactory growth of some animals in this lot.

Buamah (1964) found the high roughage group to gain significantly better than the low roughage group. However, in the current study the low roughage group gained more than the other group, even though the difference was not significant. This disagreement might be due to the different roughage used in the present work and to the slightly larger amount of grain consumed.

Increasing levels of vitamin A tended to increase the feed consumption and the 22,920 IU vitamin A supplementation daily slightly improved the feed efficiency. Perry et al. (1962) reported an improved feed consumption resulting from supplementation with vitamin A up to 20,000 IU. Kohlmier et al. (1962) also reported that vitamin A improved feed conversion, but Brethour (1964) mentioned that an addition of 20,000 IU vitamin A did not have any effect on the daily dry matter intake.

Carcass characteristics. It has been postulated that there must have been some influence of the level of roughage upon the performance of the steers. Statistical analysis of the hot carcass weight showed that heavier carcasses were obtained from the animals fed the low roughage ration than from animals fed the high roughage ration ($P < 0.05$). The influence of the level of vitamin A supplementation was not significant although the animals receiving 22,920 IU had the heaviest mean hot carcass weight.

Dressing percentages were not influenced by the different experimental treatments. The animals receiving no preformed vitamin A showed a slightly greater percentage than the others.

There were no significant differences among the lots in the rib eye area, back-fat thickness, estimated percentage of kidney knob, degree of

marbling and grade. There was a slight influence of the wintering period upon the rib eye areas.

Perry et al. (1962), Weichental et al. (1963), Klosterman et al. (1963), Richardson et al. (1964) and Newman et al. (1964) failed to find any influence of vitamin A supplementation on carcass characteristics while Brethour (1964) found that an addition of 20,000 IU vitamin A caused a significant increase in back-fat thickness. He further found that when the amount of silage fed was reduced to 5 lbs. daily, supplementation with vitamin A improved the grade. When the steers were fed a supplementation of vitamin A ration for more than 200 days, there were significant reductions ($P < 0.05$) in marbling score and carcass grade. Chapman (1964) found that supplementation of vitamin A along with vitamin E could improve the slaughter grade and could increase dressing percentage during the summer but not in winter.

The results of this study agree with that found in previous work by Busmah (1964).

Liver storage of vitamin A and carotenoids. Diplock (1963) reported that the extraction of vitamin A from liver with alkali without protection with an antioxidant resulted in a significantly lower recovery than when the extraction was made under protection of pyrogallol or by grinding the tissue with anhydrous sodium sulfate followed by extraction of the powder with ether. Since no antioxidant was used in this work, the results are assumed to be a little lower than the actual values.

It has been mentioned that increasing levels of vitamin A in the ration and increasing levels of roughage significantly ($P < 0.01$) augmented concentration of vitamin A in the liver. This has been reported by all previous workers in vitamin A nutrition. The correlation between calculated total

vitamin A intake and liver vitamin A concentration was high ($r = 0.966$); however, the relationship was not linear, as was also shown by Rousseau et al. (1956). From the data on vitamin A storage in the liver, an assumption can be made that preformed vitamin A is stored in greater amount in the liver than carotene when calculated on an equivalent basis. This was shown by lots 8 and 10 that had the same amounts of calculated vitamin A intake and so did lots 9 and 11, but the lots that received more preformed vitamin A (lot 10 and lot 11) had greater vitamin A in the liver than those which received more carotene (lots 8 and 9). Guilbert et al. (1960) and Rousseau et al. (1956) have reported the same situation.

Increasing the level of roughage significantly increased the carotenoid concentration in the liver ($P < 0.01$), as was also shown by Rousseau et al. (1956) and Wallace et al. (1964). An increase of preformed vitamin A supplementation to the ration tended to reduce carotenoid concentration in the liver. Dua et al. (1964) have shown the depressive effect of vitamin A on the utilization of carotenoids in the broiler.

A relationship between the vitamin A stored in the liver and the average daily gain was not apparent. Perry et al. (1962), Klosterman (1963), Jordan et al. (1964) and Richardson et al. (1964) reported that there was no real relationship between vitamin A storage and rate of gain. The faster gaining animals tend to use more vitamin A, and the rate of gain is increased at a limiting rate, while the amount of vitamin A stored increases at a proportional rate.

This study suggests that a supplementation of not lower than 20,000 IU preformed vitamin A daily has a beneficial effect on beef cattle production, especially when a high grain ration is used.

SUMMARY

Sixty Hereford steer calves averaging 440 lbs. in weight were randomized by weight into 6 lots to study the effect of two levels of grain in the wintering ration on the average daily gain. The ration was sorghum silage fed *ad libitum* and one pound of soybean oil meal per head daily with 4 lbs. or 8 lbs. of sorghum grain. The wintering phase lasted for 112 days and was followed by a fattening phase lasting for 213 days. In the fattening phase, the animals were reallotted into another 6 groups in a 2^3 factorial design to study the effect of different levels of grain in the wintering period, the effect of different levels of roughage and the effect of supplementation of preformed vitamin A palmitate at the levels of 30,000 IU, 15,000 IU or 0 IU. The animals were fed sorghum grain *ad libitum* along with roughage and 1.5 lbs. protein supplement daily.

After 111 days of the fattening phase, the silage supply (consumed at the rate of 16.5 lbs. and 9.5 lbs. per head daily) was exhausted and was replaced by prairie hay at the rate of 4 lbs. and 2 lbs. per head daily.

Chemical analyses showed that vitamin A content of the supplements were 15,280 IU, 8,380 IU and 0 IU per pound, respectively.

The results of the wintering phase showed that the average daily gain of the steers receiving a high grain ration was significantly greater ($P < 0.01$) than that of the other group. The average daily gains were 1.75 lbs. and 1.63 lbs. for the high and low grain ration, respectively. The results of the fattening phase showed that supplementation with the highest level of vitamin A resulted in significantly ($P < 0.05$) higher average daily gains than the other levels. The influence was also reflected in the total gain, calculated from the initial weight to the finished weight.

The average fattening gain of the steers in the low roughage group was 22 lbs. greater than that of those in the high roughage group. No significant influence of the wintering treatments was visible in any observation.

The grain consumption was increased with increasing levels of vitamin A supplementation, whereas the grain utilization was only slightly increased by the highest level of vitamin A.

The shrinkage to market of the high roughage group was significantly ($P < 0.05$) greater than that of the low roughage group; therefore the hot carcass weight of the low roughage group was significantly greater than that of the high roughage group.

The different nutritional treatments produced no significant influence upon carcass characteristics: rib eye area, back-fat thickness, estimated percentage of kidney knob, degree of marbling and grade.

Liver storage of vitamin A was highly variable among steers in a lot. Increasing vitamin A levels, however, as well as increasing levels of roughage in the ration significantly ($P < 0.01$) increased the vitamin A concentration in the liver.

Carotenoid concentration in the liver was highly influenced by the levels of roughage in the ration ($P < 0.01$).

Although there was a high correlation between total vitamin A intake and vitamin A concentration in the liver ($r = 0.966$) and although the vitamin A intake influenced the average daily gain, there was no correlation between the vitamin A stored and average daily gain.

This study suggests that supplementation with preformed vitamin A at the level of not lower than 20,000 IU daily gives a beneficial result in beef cattle production, especially when a high grain ration is used.

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LEVELS OF VITAMIN A SUPPLEMENTATION OF A STEER FATTENING RATION WITH HIGH AND LOW LEVELS OF ROUGHAGE

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Sixty Hereford steer calves averaging 440 lbs. in weight were randomized by weight into 6 lots to study the effect of two levels of grain in the wintering ration on the average daily gain. The ration was sorghum silage fed *ad libitum* and one pound of soybean oil meal per head daily with 4 lbs. or 8 lbs. of sorghum grain. The wintering phase lasted for 112 days and was followed by a fattening phase lasting for 213 days. In the fattening phase, the animals were reallotted into another 6 groups in a 2^3 factorial design to study the effect of different levels of grain in the wintering period, the effect of different levels of roughage and the effect of supplementation of preformed vitamin A palmitate at the levels of 30,000 IU, 15,000 IU or 0 IU. The animals were fed sorghum grain *ad libitum* along with roughage and 1.5 lbs. protein supplement daily.

After 111 days of the fattening phase, the silage supply (consumed at the rate of 16.5 lbs. and 9.5 lbs. per head daily) was exhausted and was replaced by prairie hay at the rate of 4 lbs. and 2 lbs. per head daily.

Chemical analyses showed that vitamin A content of the supplements were 15,280 IU, 8,380 IU and 0 IU per pound, respectively.

The results of the wintering phase showed that the average daily gain of the steers receiving a high grain ration was significantly greater ($P < 0.01$) than that of the other group. The average daily gains were 1.75 lbs. and 1.63 lbs. for the high and low grain ration, respectively. The results of the fattening phase showed that supplementation with the highest level of vitamin A resulted in significantly ($P < 0.05$) higher average daily gains than the other levels. The influence was also reflected in the total gain, calculated from the initial weight to the finished weight.

The average fattening gain of the steers in the low roughage group was

twenty-two pounds greater than that of those in the high roughage group. No significant influence of the wintering treatments was visible in any observation.

The grain consumption was increased with increasing levels of vitamin A supplementation, whereas the grain utilization was only slightly increased by the highest level of vitamin A.

The shrinkage to market of the high roughage group was significantly ($P < 0.05$) greater than that of the low roughage group; therefore the hot carcass weight of the low roughage group was significantly greater than that of the high roughage group.

The different nutritional treatments produced no significant influence upon carcass characteristics: rib eye area, back-fat thickness, estimated percentage of kidney knob, degree of marbling and grade.

Liver storage of vitamin A was highly variable among steers in a lot. Increasing vitamin A levels, however, as well as increasing levels of roughage in the ration significantly ($P < 0.01$) increased the vitamin A concentration in the liver.

Carotenoid concentration in the liver was highly influenced by the levels of roughage in the ration ($P < 0.01$).

Although there was a high correlation between total vitamin A intake and vitamin A concentration in the liver ($r = 0.966$) and although the vitamin A intake influenced the average daily gain, there was no correlation between the vitamin A stored and average daily gain.

This study suggests that supplementation with preformed vitamin A at the level of not lower than 20,000 IU daily gives a beneficial result in beef cattle production, especially when a high grain ration is used.