SUPPLEMENTATION AND PREPARATION OF THE SORGHUM GRAINS FOR GROWING AND FATTENING SWINE

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THE SORGHUM GRAINS FOR GROWING AND
FATTENING SWINE

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INTRODUCTION

In recent years the grain sorghums have been greatly improved from the standpoint of drouth resistance and grain production. This improvement has resulted in large quantities of this feed grain being economically produced in the southwestern states. It is particularly desirable that this grain be utilized in this area since the cost of transporting corn can be a large factor in a livestock feeding enterprise. Experimental work is progressing with all classes of livestock, and it is firmly established that the grain sorghums are an excellent source of carbohydrate feed. It is likewise established that, if these grains are to be fed with the expectation of producing maximum growth and feed efficiency, they must be supplemented with vitamins, minerals, and protein.

In many respects the recommendations for supplementing corn may be directly applicable to use with the sorghum grains. In other respects, however, the grain sorghums possess certain peculiarities that are not characteristic of corn. Among these is the fact that the sorghums contain from 2 to 3 percent more protein than corn; therefore, the low quality protein furnished by the grain makes up a larger part of the total protein in a grain sorghum ration than in a corn ration of equal protein content. Another peculiarity of grain sorghums is the absence of carotene which is not true of yellow corn; and, thirdly, the structure of the grain itself may present certain problems in the preparation of it for feeding purposes. It is with these problems as they apply to the use of the sorghum grains in swine fattening rations that the work herein is concerned.

LITERATURE REVIEW

Feeding Value of the Grain Sorghums

The grain sorghum varieties now commonly produced have been reported to produce a satisfactory rate and efficiency of gain by Baker (1939), Auble (1950), Fletcher (1953), and Hillier _et al._, (1954). Barham (1946) reported the grain sorghums to range from .0041 to .1667 percent tannin which has been thought to reduce palatability of the grain. The results of the above feeding tests indicate, however, that pigs eat the commonly produced grain sorghums readily. Of the varieties commonly grown in the southwestern states, Hillier _et al._, (1954) reported pigs to prefer the varieties in the order of Kafir 44-14, Westland, Redlan, Martin, and Darset.

Schneider (1947) reports the sorghums as being slightly higher in total digestible nutrients than yellow corn. Morrison (1951) recorded the net energy value of kafir and milo to be 2.2 therms less per 100 pounds than the energy value of 100 pounds of No. 2 yellow corn.

Aside from the above-mentioned characteristics, which are favorable to the grain sorghums, they are deficient in minerals, vitamins, and certain of the amino acids and must be supplemented with these nutrients.

Supplemental Protein

In 1816 Francois Magendie established the now well-known fact that certain nitrogen compounds are essential in the diets of animals. These compounds were later named proteins and Magendie produced the first evidence that all proteins were not of equal nutritional value. By the turn of the century it was widely recognized that the grains alone are not adequate for efficient utilization by swine.

Osborne et al., (1914) showed that certain proteins, which resulted in nutritional failure when fed to rats, were rendered adequate when certain of the deficient amino acids were added to the diet.

The literature on supplementation of corn rations makes up a major part of the review since it is directly applicable to grain sorghum rations in many respects.

Forbes (1909) indicated a distinct advantage in supplementing corn with tankage, linseed meal or soybeans both from the standpoint of feed efficiency and rate of gain. These supplements were of equal value, but a characteristic softness was noted in the pork of the pigs fed soybeans as a source of supplemental protein.

Godbey et al., (1926) compared tankage, fish meal, soybean meal, peanut feed, and the mixture soybean meal plus fish meal as supplements to a corn, mineral ration. The results indicated that plant protein alone was not adequate as supplemental protein, in that rate of gain and feed efficiency were definitely in favor of the rations containing a source of animal protein. Soybean meal was superior to peanut feed as the only source of protein. This was attributed to the hull content of the peanut feed. It was also shown that supplemental fish meal was superior to tankage.

Weaver (1929), feeding weanling pigs on pasture, tested the value of tankage, linseed meal, soybean meal, and ground soybeans in a fattening ration. None of the treatments were significantly different indicating, as did Robison (1941), no advantage in mixing the source of protein when pigs were fed on pasture. In another pasture feeding trial, soybean meal gave better results than either cooked or raw soybeans. In every case, it was noted that soybeans produced soft pork. This observation was also reported by Vestal (1930), Vestal _et al._, (1935), Robison (1930), and Bohstedt _et al._, (1935).

Vestal (1930), in summarizing six experiments where soybeans were used as a substitute for tankage in a corn, mineral ration for fattening pigs on pasture, reported that ground soybeans produced a more efficient and only slightly slower rate of gain than rations supplemented with tankage.

Robison (1930) indicated an advantage for cooking soybeans to be used in swine rations. In another trial comparing cooked soybeans, soybean meal, and tankage as individual supplements to a corn, alfalfa meal, mineral ration fed in dry lot, soybean meal produced a rate of gain 16 percent faster than soybeans and 5 percent faster than tankage.

Feed efficiency was not greatly different in the three lots but was slightly in favor of soybean meal. A summary of several subsequent experiments proved soybean meal equally as good as tankage from the standpoint of rate of gain and superior from the standpoint of efficiency. These results were substantiated by Vestal et al., (1935).

Considering carcass quality, Vestal et al., (1935) found the carcasses from soybean meal fed pigs to be satisfactory but not as firm as those from pigs receiving tankage as their only source of supplemental protein.

Robison (1941), recognizing a wide variation between samples of soybean meal, made a comparison of solvent extracted, solvent extracted and toasted, and expeller processed soybean meals and a tankage, linseed meal mixture as supplements to a corn, alfalfa meal, mineral ration fed in dry lot. The relative rates of gain produced by these different supplements would have made the lots of pigs reach market weight 66, 24, and 9 days later, respectively, than those fed a mixture of tankage and linseed meal. From the standpoint of feed efficiency and feed prices, the solvent extracted, the extracted and toasted, and the expeller meals were worth, respectively, 23.9, 57.0, and 79.9 percent as much as tankage. In a comparison of hydraulic and expeller meals as the only protein supplement to a corn, alfalfa meal, mineral ration, rate of gain and feed efficiency were in favor of the hydraulic processed meal.

A trial comparing levels of soybean meal in a mixture with tankage at the ratio of equal parts and two parts soybean meal to one part tankage resulted in no significant difference in rate of gain. The addition of liver meal to a tankage, soybean meal combination or equal parts of soybean meal and fish meal did not improve rate of gain or efficiency over a basal ration supplemented with equal parts of tankage and linseed meal.

As indicated by Weaver (1929), Robison (1930), and Vestal et al., (1935), the heating of soybeans resulted in a superior feed when compared with the uncooked product. Hayward et al., (1934) and Bohstedt et al., (1935), in comparing meals prepared by different processes indicated that all meals, regardless of the process, produced satisfactory gains and efficiency if they were heated to at least 250° F. for a time appropriate to the process used.

Willman et al., (1940) compared the value of tankage and Menhaden fish meal when used as a source of animal protein to supplement a corn, linseed meal, alfalfa meal, mineral ration fed to swine in dry lot. Seven trials indicated that no significant difference in rate of gain or efficiency of feed utilization was produced by the two supplements.

Vestal (1945), in a comparison of three supplemental mixtures, reported a supplement consisting of meat and bone scraps, soybean meal and alfalfa meal superior to a meat and bone scraps, alfalfa meal combination. The data also showed both of these to be inferior to a more complex supplement consisting of meat and bone scraps, fish meal, soybean meal, cottonseed meal, and alfalfa meal. When these supplements were fed to pigs on pasture, no advantage existed in favor of the complex supplement. The latter observation indicates the value of the green feed as a source of the B-complex vitamins in swine rations as was later substantiated by Vestal (1949).

Robison (1951), summarizing a 34-year period of tests using soybeans and soybean oil meal as a source of supplemental protein in swine rations, concluded the following: 1) Raw soybeans are unsatisfactory as a high-protein feed for pigs. 2) Cooked soybeans are satisfactory for producing growth but do produce soft pork. 3) In general, soybean meal, regardless of the method of preparation, is a satisfactory source of supplemental protein if it has been heated sufficiently. 4) A corn, soybean meal, alfalfa meal, mineral ration is deficient in one or more respects. The addition of other plant protein does not correct the deficiency. The addition of 0.2 percent methionine, 0.2 percent lysine, fish meal, tankage, meat scraps, dried brewers yeast, fish solubles, dried distillers solubles, or vitamin B_{12} and antibiotic will correct or greatly improve the ration. 5) Soybean meal alone is an adequate source of supplemental protein when used in a pasture fattening ration.

Hillier et al., (1954), in supplementing a grain sorghum, soybean meal ration with DL-lysine, reported an increase in daily gain and feed efficiency when the amino acid was added at levels of 0.1 and 0.2 percent of the total ration. The data also indicated the 0.1 percent level as being optimum from the standpoint of rate and efficiency of gain. In supplementing 12 and 16 percent protein rations, the addition of 0.1 percent L-lysine proved of no benefit to the lower protein ration. However, it improved daily gain by .25 of a pound and feed efficiency by .57 of a pound of feed per pound of gain when added to the ration containing 16 percent protein.

Krider *et al.*, (1950) found a corn, meat scraps, soybean meal, mineral ration supplemented with vitamin A and D inadequate. Rate of gain and feed efficiency were improved in each case by the addition of 4 or 10 percent alfalfa meal, 2 or 5 percent condensed sardine fish solubles, 2 percent condensed menhaden fish solubles, or 4 percent distillers dried solubles with 1 percent fish solubles. The addition of .50 milligrams of riboflavin per pound of feed gave a highly significant improvement over the basal ration mentioned above. The 10 percent level of alfalfa meal was superior to the 4 percent. The addition of 4 percent distillers dried solubles with 1 percent fish solubles produced a significantly faster daily gain than did the addition of 2 percent fish solubles alone. In each case the response was attributed to the water soluble vitamin content of the supplements tested.

Bloss *et al.*, (1953) found a corn, meat and bone scraps, dry lot ration inadequate. The addition of .06 percent

DL-tryptophan improved the growth rate up to that produced by the soybean meal ration. Supplementation with equal parts of soybean meal and meat and bone scraps produced a decided improvement over the corn, meat and bone scraps rations.

Geuren et al., (1950) tested the effect of adding 1 and 2 percent fish solubles and 2 percent liquid fish to an all-plant, dry lot basal ration of corn, soybean meal, alfalfa meal, mineral and supplemental vitamin A and D. The data presented indicated the addition of 2 percent liquid fish produced a rate of gain equal to that produced by 1 percent fish solubles but was inferior from the standpoint of feed efficiency. The addition of 2 percent fish solubles was superior to the other treatments in all respects.

Emery (1894), Cary (1896), and Lloyd (1899) were among the first workers to report adverse effects of cottonseed and cottonseed meal when fed to swine. They observed high mortality rates, cases of extreme sickness, and feed refusal among swine offered rations containing high levels of cottonseed feed.

Georgeson et al., (1895) reported levels of one fourth cottonseed meal to three fourths corn and equal parts of cottonseed meal and corn as highly toxic and resulting in death in six to eight weeks. This work was done after observing pigs die while following steers being fed cottonseed meal.

At this time the toxic principal in cottonseed had not been determined. It remained for Marchlewski (1899) to be the first to isolate the substance and suggest the name gossypol.

Burtis *et al*., (1901) indicated no toxic effects if cottonseed meal made up less than one fifth of the total ration. A recommended method of feeding was to feed cottonseed meal at the above rate for 2 to 3 weeks then omit the cottonseed meal for a like period. This cycle was followed until market weight was reached. Walker (1916) fed a corn, cottonseed meal diet for 60 days without ill effects.

Dinwiddie (1903) reported no toxic effects if the daily consumption of cottonseed meal was kept below 1.4 percent of body weight.

Fulmer (1905) presented data to show that the fat from hogs being fed cottonseed meal gave a positive color test with Halphin's reagent indicating that cottonseed meal in a ration is reflected by the quantity of the Halphin substance in the fat.

Hale (1930) reported no toxic effects if rations contained less than 9 percent cottonseed meal. When cottonseed meal was fed as a supplement to corn in a separate feeder, the death rate of the pigs was extremely high. This was prevented when the supplement was made up of one half tankage and one half cottonseed meal.

Withers *et al*., (1915), in studying the properties and effects of gossypol, found that an ether extract of cottonseed was highly toxic to rabbits. Likewise the crushed seeds that had been extracted were not toxic since the extraction had rendered the seeds practically free of gossypol. This work also indicated that ferrous sulfate added to the diet destroyed the toxic effects of cottonseed meal.

In more recent years a new manufacturing process has produced cottonseed meal with a low, free gossypol content that has been proven nontoxic to swine by Stephenson et al., (1952). This work also indicated a factor present in fish solubles that stimulated growth over and above that obtained from the addition of B_{12}, antibiotics or lysine when added to a corn, cottonseed meal fattening ration. Wallace et al., (1953) found cottonseed meal alone was inferior to soybean meal as the only source of supplemental protein to corn. There was an indication that ferric sulfate may be beneficial in a diet containing cottonseed meal. The addition of a surfactant or .8 percent DL-lysine was not effective in increasing rate of gain or feed efficiency, but the addition of 3 percent of aurofac produced a ration equal to the corn, soybean meal ration. The superiority of soybean meal reported here was again shown by Wallace et al., (1954).

Barrick et al., (1950) improved a corn, cottonseed meal ration by the addition of APF and ferric sulfate, but the rate of gain and feed efficiency produced was below a control ration containing meat scraps as the only source of supplemental protein.

Amino Acid Supplementation of Cottonseed Meal

Almquist (1951) evaluated cottonseed meal as being deficient in lysine, methionine, and tryptophan.

Wallace *et al.*, (1953) reported no response from the addition of .8 percent DL-lysine to a corn, cottonseed meal ration containing .25 percent ferric sulfate. Cunha *et al.*, (1951) also reported no response from additional lysine to a corn, cottonseed meal ration. Contradicting this work was that of Stephenson *et al.*, (1952) which showed a corn, cottonseed meal ration to be greatly improved by the addition of .3 percent DL-lysine. The addition of .1 percent methionine alone or in combination with DL-lysine did not improve the ration as greatly as did lysine alone. Supplementation with 6 percent fish meal was superior to .3 percent DL-lysine which indicated a factor or factors, in addition to lysine, as stimulating growth.

Miner *et al.*, (1955) in supplementing a corn, cottonseed meal, alfalfa meal ration with amino acids found the addition of .1 percent DL-lysine was an optimum level. Levels above this depressed growth, and lower levels failed to support maximum growth. The addition of .01 percent DL-tryptophan in the presence of 3 percent fish solubles produced a highly significant growth response while the addition of .05 percent methionine to the same ration did not. In each case, an improved growth rate was accompanied by improved feed efficiency. In a later trial, the addition of .005, .01, and .02 percent DL-tryptophan in the presence of 3 percent fish solubles increased rate and efficiency of gain significantly. These levels of tryptophan added alone did not result in a significant improvement.

Vitamin A Supplements

For all practical purposes the sorghum grains contain no carotene. Morrison (1951) records milo and kafir as containing .09 and .17 milligrams per pound, respectively, as compared to 2.2 milligrams per pound for yellow corn. This deficiency presents a problem in dry lot feeding of the grain sorghums. Commercial vitamin A concentrates and alfalfa meal are probably the best sources of supplemental vitamin A activity.

Steenbock *et al.*, (1920), in studies with rats, reported the yellow pigment of corn and the growth promoting property attributed to the fat soluble vitamin as being intimately associated in the corn kernel. Only by supplementing white corn with butterfat, clover, or spinach could rats receiving the deficient grain be kept alive.

Morrison *et al.*, (1921) found a white corn, tankage ration would not produce maximum gains in fattening swine. The addition of 5 percent chopped alfalfa corrected the deficiency and produced satisfactory gains. Rice *et al.*, (1926) reported a 5 percent level of alfalfa meal sufficient to prevent vitamin A deficiency symptoms in fattening swine being fed white corn or kafir for approximately five times the normal feeding period.

Guilbert *et al.*, (1935) made and substantiated the hypothesis that the vitamin A requirement of farm animals was in direct relation to body weight, and this requirement was on the order of 20-30 γ of carotene per kilogram of body weight. Guilbert _et al._, (1937) in studying the minimum requirements of vitamin A and carotene in swine, found a level of 16-22 γ per kilogram of body weight insufficient to correct night blindness. This level of supplementation was furnished by both alfalfa meal and carotene in oil. An increased level, 25-39 γ per kilogram of body weight was effective in correcting night blindness and allowed the pigs to gain at a normal rate. At this level liver storage of vitamin A was small as compared with no storage in the animals receiving the lower level. The minimum requirement of vitamin A was established as 5.8 to 7.5 γ per kilogram of body weight utilizing cod liver oil as a supplemental source. A lower level, 3.7 to 4.4 γ per kilogram of body weight was not effective in correcting deficiency symptoms. Hentges (1952b) noted that 25 γ of purified carotene per kilogram of body weight was required to restore normal plasma levels of vitamin A and provide a small amount of liver storage in pigs previously depleted to 7 γ of vitamin A per 100 milliliters plasma. A level of 17.5 γ restored plasma levels to normal but did not provide any storage. A 10 γ level overcame gross deficiency symptoms. Daily gains were reported as satisfactory on all three levels but increased directly with the level fed.

Hentges et al., (1949) compared two levels of dehydrated alfalfa meal with sun-cured alfalfa meal and pelleted dehydrated alfalfa as additions to a corn, soybean meal ration.

The results show that a 3 percent level of either dehydrated alfalfa meal or pelleted dehydrated alfalfa was sufficient to maintain blood and liver levels of the vitamin and to produce adequate growth. The same level of the sun-cured product produced satisfactory growth, but a drop in storage was evident. Six percent alfalfa meal doubled the stores produced by the 3 percent level.

Hentges <u>et al</u>., (1952a), in a comparison of swine feeds as sources of pro-vitamin A, recorded the effects of pelleted, dehydrated alfalfa, dehydrated alfalfa meal, sun-cured alfalfa meal, yellow corn, and carotene in oil on pigs depleted to 5 γ of vitamin A per 100 milliliters plasma. Each supplement was fed at a level to provide 25 γ per kilogram body weight per day. The average daily gain produced was approximately equal on all levels. Restoration of the plasma vitamin A was complete in 14 days in pigs receiving the dehydrated products whereas 63 days were required in the case of sun-cured meal and yellow corn. Carotene in oil was slightly inferior to the dehydrated feeds. This was attributed to the presence of alpha carotene in the product.

Bohman <u>et al</u>., (1953), in an effort to determine the maximum level of alfalfa meal that could be economically utilized by swine, tested levels ranging from 10 to 60 percent. Fifty and 60 percent levels were detrimental from the standpoint of daily gain and feed efficiency, but 10 and 30 percent levels were not significantly different from the standpoint of rate and efficiency of gains. The total feed required per 100 pounds gain was in direct proportion to the amount of alfalfa meal in the ration while the amount of grain required was reduced considerably as the level of alfalfa meal increased. A marked enlargement of the digestive tract was noted in pigs receiving the 30 and 50 percent levels of alfalfa meal.

The Value of the Chromic Oxide Method of Determining Digestibility of Rations Fed *ad libitum* to Swine

The chromic oxide method of determining digestibility has been shown to be useful in experiments with rats by Schurch *et al.*, (1950) and with humans by Irwin *et al.*, (1951). Schurch *et al.*, (1952) tested the value of this method when fed *ad libitum* to swine. The results reported by the method were consistent with the results obtained using a total collection digestion trial as a control. The chromic oxide was mixed at the rate of 1 percent of the total ration, and random samples of feces were collected for four days following a four-day preliminary period. A previous experiment indicated no analytical difference in feces collections made on the fourth, fifth, or sixth day.

Clawson et al., (1955) reported results similar to Schurch *et al.*, (1952) in that digestion coefficients determined with the use of chromic oxide under *ad libitum* feeding conditions were in very close agreement with those determined using a total collection method with the control animals. It was observed that some variation existed between collections from the same animal made at different periods during the day. A random sample collection over four days, however, tended to yield an accurate average digestion coefficient that offset these differences.

EXPERIMENTAL

Experiment I

General

The first experiment was designed to test the relative value of soybean meal, tankage, fish solubles, and combinations of these as protein supplements to grain sorghum rations containing mineral and alfalfa meal when fed to swine in dry lot. Rate of gain and feed efficiency were used as criteria for measuring the relative value of the different supplements. The data is based on two trials, one conducted in the summer of 1954, the other in the winter of 1954-55.

Experimental Animals (Summer, 1954)

Eighty weanling pigs representing different breeds were allotted equally on the basis of breeding, weight, and sex to ten lots of eight pigs each which provided a replication of the five treatments. The average initial weight of the animals was 46.3 pounds.

Experimental Animals (Winter, 1954-55)

Eighty weanling pigs, 64 purebreds and 16 crossbreds, were allotted as in the previous trial. The average initial weight was 53.1 pounds.

Housing

The pigs were housed in pens (6 x 30 feet) of 8 pigs each in a well ventilated, concrete-floored, feeding barn.

The animals were removed from the pens only for weighing. Water was supplied by one automatic waterer in each pen. One self feeder (six opening) was used in each pen to supply feed.

Rations

Each lot of pigs was self fed one of the mixed rations shown in Table I. The chemical composition of the feeds appears in Tables II and III.

Table I

Percentage Composition of Rations Fed
Experiment I - Summer 1954 and Winter 1954-55

Ration Number	I	II	III	IV	V
Kafir 44-14 (ground)	75.5	78.4	82.1	80.6	75.2
Alfalfa meal (dehydrated)	5.0	5.0	5.0	5.0	5.0
Soybean meal	15.9	8.0	---	5.8	13.2
Tankage	---	5.5	10.6	---	---
Blood meal	---	---	---	5.0	---
Fish solubles	---	---	---	---	3.0
Bone meal	2.0	1.5	.7	2.0	2.0
Salt	1.0	1.0	1.0	1.0	1.0
Aurofac[1]	.5	.5	.5	.5	.5
Fortafeed[2]	.1	.1	.1	.1	.1
Total	100.0	100.0	100.0	100.0	100.0
Total protein	16.5	16.6	16.5	16.6	16.3

[1]Supplied antibiotic and B_{12} at the following rates: .009 g. of auromycin and .009 mg. of B_{12} per pound of feed.

[2]Supplied 2.0 mg. riboflavin, 4.0 mg. pantothenic acid, 9.0 mg. niacin, and 90.0 mg. choline per pound of feed.

The rations were prepared in the following manner: Kafir 44-14, purchased on the open market, was ground to medium fineness and mixed with the other components. A commercial B-complex vitamin supplement and an antibiotic supplement were added as indicated in Table I. Alfalfa meal was fed as a source of supplemental vitamin A. Each ration was thought to be adequate with respect to the mineral and vitamin requirements of the animals.

Methods of Collecting Data

The pigs were weighed every 14 days until they approached 200 pounds. At this time weighing was done more frequently to obtain a final weight as close to 200 pounds as possible. All animals were removed at or near 200 pounds.

Feed efficiency was based on total feed consumed by each lot during the trial.

Results and Discussion

Trial I - Summer 1954

The results of Trial I are summarized in Table IV. An analysis of variance (Snedecor 1946), conducted on individual daily gains and average feed consumption per 100 pounds of gain, showed significant differences ($P < .05$) among treatments with respect to daily gains and no significant differences with respect to feed required per 100 pounds of gain. The multiple range test (Duncan 1955) showed no significant difference in the daily gains for the pigs receiving soybean meal alone (Lot I) or in combination with fish solubles (Lot V); however, the ration containing fish solubles produced a significantly ($P < .05$) higher rate of gain than did tankage alone (Lot II) or soybean meal plus blood meal (Lot IV). The rations containing tankage alone (Lot II), soybean meal

Table II

Chemical Composition of Feeds
Experiment I (Trial I) and Experiment III - Summer 1954

	H_2O %	Ash %	Protein %	Fat %	Ca %	P %	Crude Fiber %	NFE %
Kafir 44-14	9.66	1.53	10.00	3.93	.11	.64	2.20	72.68
Alfalfa meal	6.49	11.25	23.81	3.46	1.23	.84	18.61	36.38
Blood meal	6.30	6.77	82.44	2.20	1.24	.33	1.10	1.19
Fish solubles	43.08	12.41	32.25	15.04	.10	.10	.09	---
Soybean meal	7.13	6.74	50.87	2.57	.34	.40	6.60	26.09
Tankage	5.22	16.31	61.94	11.68	3.79	.12	4.50	.35

Table III

Chemical Composition of Feeds
Experiments I (Trial II), II, and IV

	H_2O %	Ash %	Protein %	Fat %	Ca %	P %	Crude Fiber %	NFE %
Kafir 44-14	9.66	1.53	10.00	3.93	.11	.64	2.20	72.68
Alfalfa meal	6.05	10.34	23.50	3.54	1.45	.64	18.19	38.48
Blood meal	6.30	6.77	82.44	2.20	1.24	.33	1.10	1.19
Fish solubles	43.92	12.12	32.12	14.96	.11	.10	.08	---
Soybean meal	7.13	6.74	50.87	2.57	.34	.40	6.60	26.09
Tankage	5.22	16.31	61.94	11.68	3.79	.12	4.50	.35
Cottonseed meal[1]	7.90	5.94	39.72	4.05	.21	.93	9.72	32.61

[1]The meal used in Experiment II contained 0.072 percent free gossypol with a nitrogen solubility of 79.51 in 0.02 N NaOH. The analysis was made by the Western Cotton Oil Company of Abilene, Texas.

Table IV
Summary of Results
Experiment I
Trial I - Summer 1954

Ration Number	I	II	III	IV	V
Source of Supplemental Protein	soybean meal	tankage	soybean meal + tankage	soybean meal + blood meal	soybean meal + fish solubles
Number of pigs in lot	15[1]	16	16	16	15[2]
Av. initial weight (lbs.)	46.0	45.5	46.5	47.0	46.5
Av. final weight (lbs.)	201.0	199.0	195.0	201.0	206.0
Av. total gain (lbs.)	155.0	153.5	148.5	154.0	159.5
Av. daily gain (lbs.)	1.49	1.36	1.40	1.46	1.60
Av. days on feed	105.0	113.0	106.2	105.0	100.0
Av. feed per 100 lbs. gain (lbs.)	327.5	343.5	370.5	348.5	349.5
Cost of feed per 100 lbs. of gain	$9.91	$10.57	$11.34	$10.91	$10.83

[1]One pig assumed stolen.

[2]One pig died--cause unknown.

plus tankage (Lot III), or soybean meal plus blood meal (Lot IV) did not show a significant advantage over the basal ration containing soybean meal alone (Lot I) and did not differ significantly among themselves.

Although the addition of fish solubles (Lot IV) increased the daily gains produced by a grain sorghum, soybean meal, alfalfa meal, mineral ration (Lot I) by 6.9 percent over the basal ration, the comparative feed cost per 100 pounds of gain was in favor of the basal ration which produced 100 pounds of gain 8.4 percent cheaper than did the ration containing fish solubles. From the standpoint of economy, the increased daily gain did not offset the increased cost. However, the pigs receiving the fish solubles could have been marketed at least five days earlier than any other pigs in the experiment. The ration supplemented with tankage alone (Lot II) produced an8.7 percent lower rate of gain that was 6.2 percent more expensive than gains produced by the basal ration. The use of tankage (Lot III) or blood meal (Lot IV) as a substitute for part of the soybean meal did not increase rate of gain but increased the cost of gain by 12.6 and 9.2 percent, respectively.

Trial II - Winter 1954-55

The results of Trial II of this experiment are summarized in Table V. Statistical analysis, as in Trial I, indicated no significant differences in daily gain or feed efficiency. The basal ration (Lot I) produced a slightly higher rate of

Table V
Summary of Results
Experiment I
Trial II - Winter 1954-55

Ration Number Source of Supplemental Protein	I soybean meal	II tankage	III soybean meal + tankage	IV soybean meal + blood meal	V soybean meal + fish solubles
Number of pigs in lot	16	16	16	15[1]	16
Av. initial weight (lbs.)	51.4	51.5	51.6	59.8	51.3
Av. final weight (lbs.)	196.7	195.1	200.8	201.2	199.4
Av. total gain (lbs.)	145.3	143.6	149.2	141.4	147.8
Av. daily gain (lbs.)	1.75	1.61	1.74	1.65	1.72
Av. days on feed	83.0	89.4	85.9	85.5	86.2
Av. feed per 100 lbs. gain (lbs.)	362.1	377.8	364.1	388.3	382.8
Cost of feed per 100 lbs. of gain	$10.96	$11.63	$11.15	$12.17	$11.86

[1] One pig became severely infected with Parakeratosis and was removed.

gain and required less feed per 100 pounds of gain than any of the other treatments. The basal ration was superior by 8.0 and 5.7 percent, respectively, over the rations containing tankage alone (Lot II) and soybean meal plus blood meal (Lot IV). For all practical purposes the rate of gain produced by a soybean meal tankage mixture (Lot III) and a soybean meal fish solubles mixture was equal to that produced by the basal ration.

As in the previous trial, the basal ration was the most efficient of the rations tested and produced 100 pounds of gain on 4.2, 0.5, 6.7, and 5.4 percent less feed, respectively, than did the rations supplemented with tankage alone, soybean meal plus tankage, soybean meal plus blood meal, or soybean meal plus fish solubles. The basal ration produced gains from 1.8 to 7.6 percent cheaper than any other ration tested.

Trials I and II Combined

The results of the Trials I and II combined are summarized in Table VI. An analysis of variance (Snedecor 1946) indicated there was no significant differences among the treatments with respect to daily gains or feed efficiency. From the standpoint of daily gains, the ration supplemented with a fish solubles, soybean meal mixture was superior to the basal ration by 2.4 percent, but economy of gain was in favor of the basal ration by 8.0 percent which indicates little, if any, advantage in the addition of the fish solubles. The basal ration was superior to the ration

Table VI
Summary of Results
Experiment I
Trials I and II Combined

Ration Number Source of Supplemental Protein	I soybean meal	II tankage	III soybean meal + tankage	IV soybean meal + blood meal	V soybean meal + fish solubles
Av. initial weight (lbs.)	48.7	48.5	49.1	53.4	48.9
Av. final weight (lbs.)	198.8	197.0	197.9	199.5	202.7
Av. total gain (lbs.)	150.1	148.5	148.9	147.7	153.6
Av. daily gain (lbs.)	1.60	1.49	1.57	1.55	1.66
Av. days on feed	94.0	101.3	96.1	95.2	93.1
Av. feed per 100 lbs. gain (lbs.)	344.8	361.7	367.3	368.4	365.8
Cost of feed per 100 lbs. of gain	$10.44	$11.10	$11.25	$11.54	$11.34

supplemented with tankage alone, soybean meal plus tankage, or soybean meal plus blood meal by 6.8, 3.1, and 6.6 percent, respectively, with respect to efficiency of feed utilization. For the two-year period, the basal ration was from 5.9 to 8.5 percent more economical in producing gains than any other ration tested.

In conclusion, a grain sorghum, soybean meal, alfalfa meal ration properly supplemented with vitamins and minerals produced a very satisfactory rate and efficiency of gain. Only by the addition of 3.0 percent fish solubles was the rate of gain increased slightly. This increase was offset by the increased cost of the ration. Addition of tankage or blood meal did not prove beneficial, and soybean meal alone proved superior to tankage alone as a protein supplement to a grain sorghum ration for swine fed in dry lot.

In the analysis of each of the two trials making up Experiment I a test was made to determine if there was an advantage in replicating each treatment on two lots of 8 pigs each, as was done in the experiments reported herein, rather than subjecting 16 pigs in the same lot to a particular treatment without replication. In Trial I, an F test (Snedecor 1946) indicated the replication variance to be significant ($P < .01$) and significant ($P < .05$) in Trial II. On the basis of these tests the replication of treatments is of value. It must be recognized that these tests were based on a relatively short period of experimentation. Similar tests conducted over a longer period of time could yield results to the contrary.

Experiment II

General

The second experiment was designed to test the effectiveness of cottonseed meal as a replacement for soybean meal and the value of supplementing cottonseed meal with L-lysine in a grain sorghum, alfalfa meal, mineral ration. The criteria for measuring the results were rate of gain and feed efficiency. The experiment was conducted during the winter, 1954-55, being initiated December 24, 1954.

Experimental Animals

Twenty purebred pigs representing different breeds were allotted equally on the basis of breed, weight, and age to four lots in a randomized block design. All rations were assigned at random within each block. The average initial weight of the pigs was 64.2 pounds.

Housing

The pigs were housed in individual concrete-floored pens ($3\frac{1}{2}$ x $5\frac{1}{2}$ feet) in a well ventilated building. The animals were removed from the pens only for weighing. Individual self feeders were used to supply feed. Water was supplied to each pig in a small trough in which fresh water was placed two or more times daily.

Rations

Each lot of pigs was self fed one of the mixed rations shown in Table VII. Kafir 44-14 purchased on the open market was ground and mixed with the other ingredients. The control ration, containing only soybean meal as a source of supplemental protein was fed Lot I. Lot II received the same ration with the exception that the soybean meal was replaced with cottonseed meal containing .072 percent free gossypol and having a nitrogen solubility of 79.51 in 0.02 N NaOH. In Lot III only one half the soybean meal was replaced with cottonseed meal. Lot IV received the same ration as Lot II but contained 0.2 percent L-lysine. The rations were assigned to the individual pigs within each block at random.

Table VII

Percentage Composition of Rations Fed[1]
Experiment II - Winter 1954-55

Ration Number	I	II	III	IV
Kafir 44-14 (ground)	74.3	73.4	74.1	73.4
Soybean meal	14.6	---	7.4	---
Cottonseed meal	---	15.5	7.4	15.5
Alfalfa meal (dehydrated)	7.5	7.5	7.5	7.5
Aurofac[2]	0.5	0.5	0.5	0.5
Fortafeed[3]	0.1	0.1	0.1	0.1
Salt	1.0	1.0	1.0	1.0
Bone meal	2.0	2.0	2.0	2.0
L-lysine[4]	---	---	---	0.2
Total	100.0	100.0	100.0	100.0
Total protein	16.05	16.02	16.00	16.02
Total lysine	0.7	0.5	0.6	0.7

[1]Adequate vitamin D was furnished by a weekly feeding of cod liver oil.

[2]Supplied .009 gm. of auromycin and .009 mg. of B_{12} per pound of feed.

[3]Supplied 2.0 mg. riboflavin, 4.0 mg. pantothenic acid, 9.0 mg. niacin, and 90 mg. choline per pound of feed.

[4]The L-lysine, 98 percent pure, was furnished by Charles Pfizer, Inc.

Methods of Collecting Data

The pigs were weighed every 14 days until they approached a weight of 150 pounds. At this time more frequent weighings were made to facilitate removal at a final weight as near 150 pounds as possible. Feed efficiency was based on the individual feed consumption for the entire trial. Periodic weigh-backs were made, however, for the purpose of checking the progress of the experiment.

Results and Discussion

The results of Experiment II are summarized in Table VIII. Statistical analysis of variance (Snedecor 1946) resulted in a low level of significance ($P < .10$) with respect to difference in daily gains and no significant differences among treatments with respect to the amount of feed required per 100 pounds of gain. Comparisons of the mean daily gains by the method of least significant differences (Snedecor 1946) showed the rate of gain produced by the basal ration (Lot I) which contained soybean meal alone as a source of supplemental protein, to be significantly higher than the rate of gain produced by the rations containing cottonseed meal alone (Lot II) or cottonseed meal supplemented with 0.2 percent L-lysine (Lot IV). The replacement of soybean meal with cottonseed meal reduced rate of gain by 18.6 percent and increased the amount of feed required per 100 pounds of gain by 12.7 percent.

When only one half of the soybean meal was replaced by cottonseed meal (Lot III), daily gain and feed efficiency were reduced by 3.6 and 4.2 percent, respectively. The addition of 0.2 percent L-lysine to the ration containing cottonseed meal alone (Lot IV) resulted in a 4.8 percent increase in rate of gain with only a 0.16 percent reduction in the amount of feed required per 100 pounds gain. In general, the economy of gain was reduced directly as the proportion of cottonseed meal in the ration was increased.

Table VIII

Summary of Results
Experiment II - Winter 1954-55

Ration Number	I	II	III	IV
Source of Supplemental Protein	soybean meal	cottonseed meal	cottonseed meal + soybean meal	cottonseed meal + lysine
Number of pigs in lot	4	4	4	4
Av. initial weight (lbs.)	64.6	61.6	61.6	69.0
Av. final weight (lbs.)	155.0	149.0	157.0	154.8
Av. total gain (lbs.)	90.4	87.4	95.4	85.8
Av. daily gain (lbs.)	1.94	1.53	1.87	1.74
Av. days on feed	47.0	57.4	52.0	49.2
Av. feed per 100 lbs. gain (lbs.)	371.7	426.0	387.8	425.4
Cost of feed per 100 lbs. gain	$11.02	$12.53	$11.45	$12.56

In conclusion, the supplementation of cottonseed meal with 0.2 percent of L-lysine did not improve rate and efficiency of gain to the point that the result was comparable to the basal ration supplemented with soybean meal alone. These results indicate that lysine is probably the first limiting amino acid in a grain sorghum, cottonseed meal, alfalfa meal, mineral ration but not the only limiting amino acid in this combination of feeds.

On the basis of this experiment it appears that soybean meal contains a factor or factors over and above its lysine content that make it superior to cottonseed meal for use in swine rations.

Substituting cottonseed meal for one half of the soybean meal proved detrimental. The presence of cottonseed meal in the ration was observed to increase the tendency of the pigs to waste feed.

Experiment III

General

The third experiment was designed to determine the optimum level of alfalfa meal to be fed as a vitamin A supplement to a grain sorghum, soybean meal, blood meal ration for swine fed in dry lot. The trial was to further indicate the effect of an increased fiber content of the ration on rate and economy of gain. Rate of gain and efficiency of feed utilization were used as the criteria for interpreting the results. The experiment was conducted during the summer of 1954, being initiated June 12, 1954.

Experimental Animals

Sixty-four purebred pigs representing different breeds were allotted as equally as possible on the basis of breed, weight, and sex to 8 lots of 8 pigs each which provided a replication of the 4 treatments. The average initial weight of the pigs was 53.9 pounds. The lots were assigned the treatments used at random.

Housing

The pigs were housed in the same manner as those in Experiment I.

Rations

Each lot of pigs was fed one of the mixed rations shown in Table IX. The chemical analysis of the feeds used appears in Table II. All rations were thought to contain adequate amounts of mineral and vitamins with the exception of ration I which contained no alfalfa meal or other supplemental source of vitamin A. The levels of alfalfa meal fed were as follows: ration I, 0.0 percent; ration II, 5.0 percent; ration III, 7.5 percent; and ration IV, 10.0 percent. The rations were assigned to the lots at random. Aside from the different levels of alfalfa meal, the other components of the rations remained the same with the exception of the grain and soybean meal, which fluctuated to provide a ration containing 16 percent protein.

Methods of Collecting Data

Pigs were weighed individually every 14 days until they approached 200 pounds, at which time weighing was done more frequently to facilitate the removal of each pig as close to that weight as possible. Feed efficiency was based on total feed consumed over the entire feeding period. At the end of the experiment, 3 pigs from each treatment were selected at random to be slaughtered to furnish blood and liver samples for analysis. The level of liver vitamin A and the plasma level of carotene and vitamin A were determined.

Table IX

Percentage Composition of Rations Fed
Experiment III - Summer 1954

Ration Number	I	II	III	IV
Kafir 44-14 (ground)	84.9	80.6	78.4	76.3
Alfalfa meal (dehydrated)	0.0	5.0	7.5	10.0
Soybean meal	6.5	5.8	5.5	5.1
Blood meal	5.0	5.0	5.0	5.0
Bone meal	2.0	2.0	2.0	2.0
Salt	1.0	1.0	1.0	1.0
Aurofac[1]	.5	.5	.5	.5
Fortafeed[1]	.1	.1	.1	.1
Total	100.0	100.0	100.0	100.0
Total protein	16.1	16.2	16.2	16.2

[1]Antibiotic, B_{12} and B-vitamins added at the same rate as in Experiments I and II.

Results and Discussion

The results of Experiment III are summarized in Table X. Statistical analysis of variance (Snedecor 1946) conducted on individual daily gains and average feed consumption per 100 pounds of gain indicated no significant differences among the 0.0, 5.0, 7.5, and 10.0 percent levels of alfalfa meal from the standpoint of daily gain or efficiency of feed utilization. This is in agreement with Bohman *et al.*, (1953). The trend was toward a slightly reduced daily gain when alfalfa meal was added to the ration (Lot II, III, and IV); however, the reduction was not appreciable in any case. The feed required per 100 pounds of gain was increased 8.8, 6.9, and 10.1 percent, respectively, when the 5.0, 7.5, and 10.0 percent levels of alfalfa meal were added to the ration.

On the basis of this experiment, the omission of a source of vitamin A from a dry lot ration cannot be recommended since one pig in Lot I developed definite vitamin A deficiency symptoms during the last few days of the feeding period. This particular pig, on slaughter, showed 1.17 γ of vitamin A per gram of dry liver and 12.0 γ per 100 milliliters of blood plasma.

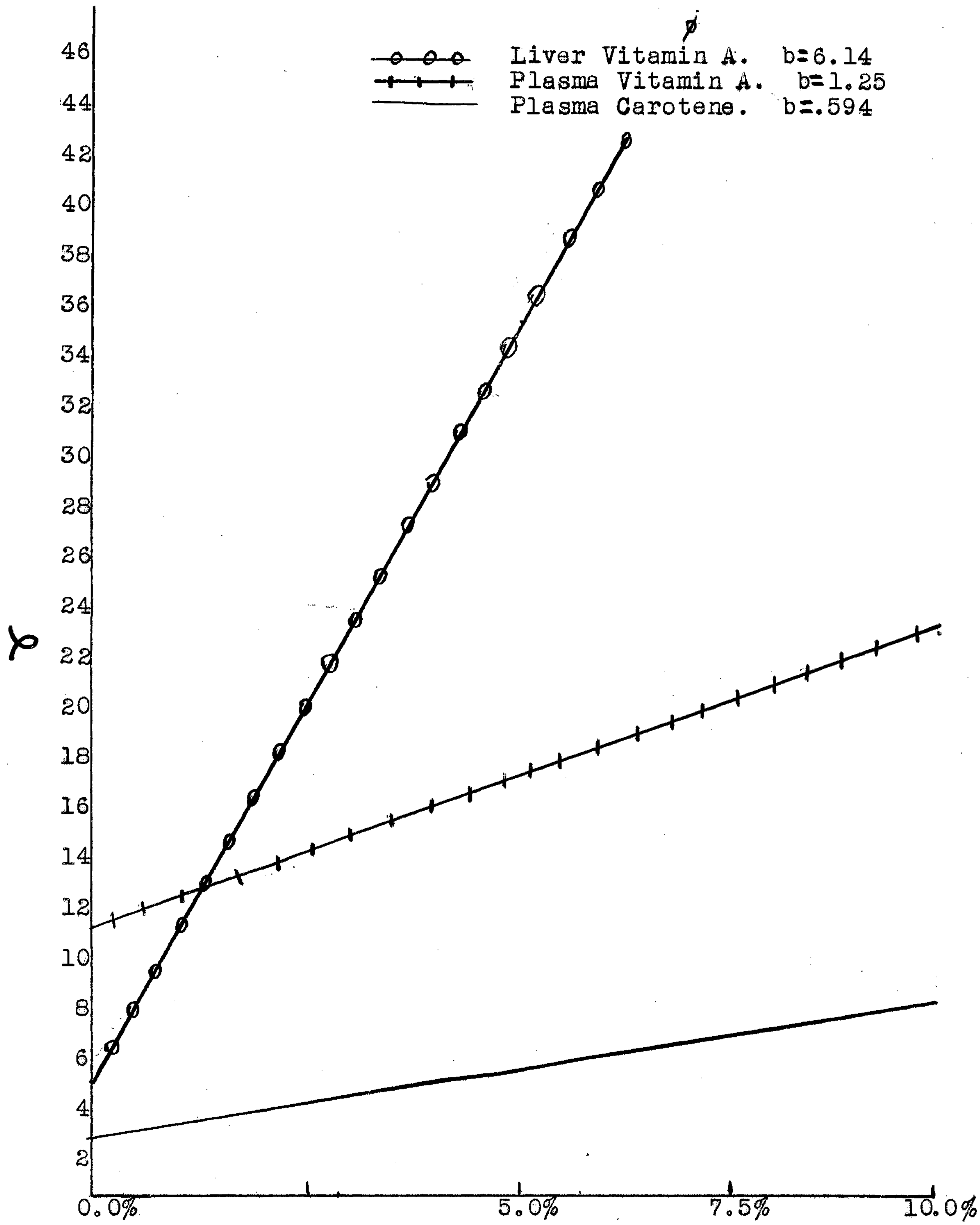
Table X

Summary of Results
Experiment III - Summer 1954

Ration Number	I	II	III	IV
Number of pigs in lot	15[1]	16	16	16
Av. initial weight (lbs.)	54.1	53.9	54.0	53.9
Av. final weight (lbs.)	202.9	209.7	203.9	205.9
Av. total gain (lbs.)	148.8	155.8	149.9	152.0
Av. daily gain (lbs.)	1.56	1.53	1.45	1.53
Av. days on feed	97.3	102.0	102.4	100.1
Av. feed per 100 lbs. gain (lbs.)	312.1	341.1	335.7	347.0
Cost of feed per 100 lbs. gain	$10.30	$11.23	$11.03	$11.38
Av. plasma carotene (γ/100 ml.)	3.8	4.1	5.3	10.0
Av. plasma vitamin A (γ/100 ml.)	7.6	22.3	17.71	23.3
Av. liver vitamin A (γ/gm., dry)	5.7	32.7	54.3	65.4

[1]One pig died prior to completion of the experiment. No visual symptoms of vitamin A deficiency were present.

The increasing levels of alfalfa meal produced a linear response (Figure I) with respect to plasma carotene and vitamin A as well as liver storage. The linear nature of the vitamin A stores was observed by Hentges _et al_., (1949). Analysis of variance (Snedecor 1946) showed no significant differences between treatments with respect to the carotene content of the blood. An analysis of the blood and liver



Level of Alfalfa Meal

Figure I

Regression of Liver Vitamin A, Plasma Carotene, and Plasma Vitamin A on Increasing Levels of Alfalfa Meal content of vitamin A resulted in highly significant ($P < .01$) differences among the levels of alfalfa meal. With respect to plasma vitamin A, the significance was established by the multiple range test (Duncan 1955) as being between the ration containing no alfalfa meal and those containing alfalfa meal. With respect to liver storage, the 5.0, 7.5, and 10.0 percent levels were not significantly different from each other; however, the 5.0 percent level did not produce liver stores significantly larger than those present in the pigs receiving the 0.0 level while the 7.5 and 10.0 percent levels did produce liver stores that were significantly higher than that produced by the 5.0 percent level.

In conclusion, the ration containing no source of vitamin A activity produced a satisfactory rate and efficiency of gain; however, this practice cannot be recommended since one pig did develop vitamin A deficiency symptoms near the end of the experiment. The 5.0, 7.0, and 10.0 percent levels of alfalfa meal produced gains that were not significantly different. Plasma carotene and vitamin A and liver storage of vitamin A were increased in proportion to the levels of alfalfa meal fed.

Experiment IV

General

The fourth experiment was designed to test the effects of supplementing a grain sorghum, soybean meal, blood meal ration with 5.0, 7.5, and 10.0 percent levels of alfalfa meal and with a commercial vitamin A supplement in gelatin. Rate of gain and efficiency of feed utilization as well as blood and liver levels of carotene and vitamin A were used as the criteria for interpreting the results. The experiment was conducted during the winter of 1954-55, being initiated December 18, 1954.

Experimental Animals

Sixty-four purebred pigs representing different breeds were allotted as equally as possible to 8 lots as in Experiment III. The average initial weight of the pigs used was 62.0 pounds.

Housing

The pigs were housed in the same manner as in Trial III.

Rations

Each lot of pigs was self fed one of the mixed rations shown in Table XI. The chemical composition of the feeds appears in Table III. Each ration was thought to contain adequate minerals and vitamins. Kafir 44-14 was purchased on the open market. A soybean meal, blood meal mixture furnished the supplemental protein. Alfalfa meal was fed as a vitamin A supplement at the following levels: Lot I, 5.0 percent; Lot II, 7.5 percent; Lot III, 10.0 percent. Lot IV received a commercial vitamin A preparation at a supplemental rate which was designed to equal a ration containing 10.0 percent fresh alfalfa meal. The treatments were assigned at random to the various lots.

Table XI

Percentage Composition of Rations Fed
Experiment IV - Winter 1954-55

Ration Number	I	II	III	IV
Kafir 44-14 (ground)	80.6	78.4	76.3	84.9
Alfalfa meal (dehydrated)	5.0	7.5	10.0	0.0
Soybean meal	5.8	5.5	5.1	6.5
Blood meal	5.0	5.0	5.0	5.0
Bone meal	2.0	2.0	2.0	2.0
Salt	1.0	1.0	1.0	1.0
Aurofac[1]	.5	.5	.5	.5
Fortafeed[1]	.1	.1	.1	.1
Vitamin A in gelatin	0.0	0.0	0.0	3.2 g.
Total	100.0	100.0	100.0	100.0
Total protein	16.2	16.2	16.2	16.1
Total USP units of vitamin A activity per pound of feed	1150.0	1725.0	2300.0	8000.0

[1]Antibiotic, B_{12}, and B-vitamins were furnished at the same rates as in Experiment III.

Methods of Collecting Data

Rate of gain, efficiency of feed utilization, blood and liver levels of carotene, and vitamin A were collected in the same manner as in Experiment III.

Results and Discussion

The results of Experiment IV are summarized in Table XII. An analysis of variance (Snedecor 1946) showed no significant differences among treatments from the standpoint of daily gain or feed consumption per 100 pounds of gain. With respect to the lots receiving 5.0, 7.5, and 10.0 percent levels of alfalfa meal, daily gains were essentially equal, the widest difference between treatments being .09 pound daily. With respect to feed efficiency, the amount of feed required per 100 pounds of gain was in direct proportion to the amount of alfalfa meal in the ration. The ration containing 7.5 (Lot II) and 10.0 percent alfalfa meal (Lot III) were 2.6 and 6.1 percent less efficient, respectively, than the ration containing 5.0 percent alfalfa meal (Lot I).

Table XII

Summary of Results
Experiment IV - Winter 1954-55

Ration Number	I	II	III	IV
Number of pigs in lot	16	14[1]	13[2]	15[3]
Av. initial weight (lbs.)	60.9	66.3	59.8	61.0
Av. final weight (lbs.)	198.7	203.7	202.5	200.9
Av. total gain (lbs.)	137.8	137.4	142.7	139.9
Av. daily gain (lbs.)	1.70	1.74	1.74	1.79
Av. days on feed	82.1	80.2	81.3	77.7
Av. feed per 100 lbs. gain (lbs.)	388.1	398.5	413.4	394.4
Cost of feed per 100 lbs. gain	$11.92	$12.21	$12.63	$12.66
Av. plasma carotene (γ/100 ml.)	3.4	3.4	3.9	2.7
Av. plasma vitamin A (γ/100 ml.)	10.4	9.2	9.6	13.3
Av. liver vitamin A (γ/gm., dry)	74.8	85.7	114.4	780.7

[1]Two pigs removed with severe parakerotosis.
[2]Three pigs removed with severe parakerotosis.
[3]One pig removed with severe parakerotosis.

In Lot IV, vitamin A in gelatin was substituted for alfalfa meal at a rate to provide 8000 USP units of vitamin A per pound of feed. This substitution should have provided approximately the same amount of vitamin A activity as the addition of 10 percent of fresh alfalfa meal. On the basis of a chemical analysis of the alfalfa meal and the liver storage of vitamin A reported above, it is apparent that the ration containing the commercial vitamin supplement contained far more vitamin A activity than did the ration containing 10 percent alfalfa meal. The ration containing the commercial vitamin supplement was 1.6 percent less efficient than the 5.0 percent alfalfa meal ration. The cause for this is not entirely clear. It could have been due to feed wastage or the absence of alfalfa meal could have improved the palatability to the point that excessive feed consumption reduced efficiency. The lots receiving 7.5 and 10.0 percent levels of alfalfa meal were 1.1 and 4.6 percent less efficient in feed utilization than the lot receiving the vitamin A supplement. With respect to economy of gain, the 5.0 percent level of alfalfa meal produced 100 pounds of gain for 29 cents and 71 cents less than the 7.5 percent and 10.0 percent levels of alfalfa meal, respectively, and for 74 cents less than the commercial vitamin A supplement.

A statistical analysis of variance (Snedecor 1946) indicated no significant differences between the lots with respect to plasma carotene or plasma vitamin A. The analysis also indicated a highly significant difference between the lots with respect to liver storage of vitamin A. The multiple range test (Duncan 1955) indicated the significance ($P < .01$) as being between the vitamin A supplement (Lot IV) and the other treatments containing the graded levels of alfalfa meal. No significant differences were found between liver storage values produced by the different levels of alfalfa meal. The probable cause of the wide difference in liver storage resulting from the two supplemental sources was the low carotene content of the alfalfa meal fed. As mentioned previously, the ration containing the commercial vitamin A contained approximately 8000 USP units of vitamin A while the ration containing 10.0 percent alfalfa meal contained approximately 2300 USP units of vitamin A activity per pound of feed.

Experiment V

General

The fifth experiment was designed to determine the optimum degree of fineness for grinding sorghum grain to be included in a mixed ration for swine fed in dry lot. Dry matter digestibility was determined on rations containing whole, rolled, coarsely ground, and finely ground kafir 44-14. The rations fed differed only in the preparation of the sorghum grain. The digestion trials were conducted in the same manner as reported by Schurch *et al.*, (1952) using chromic oxide as an index material. Digestibility, rate of gain, and economy of gain were used as criteria for interpreting the results. The trial was conducted during the spring of 1955 being initiated May 1, 1955.

Experimental Animals

Sixteen weanling Chester White barrows were allotted equally on the basis of weight to 4 lots of 4 pigs each in a randomized block design. The average initial weight was 41.2 pounds. Rations were assigned to the pigs within each block at random. All animals were individually fed and cared for.

Housing

The pigs were housed in individual pens in the same manner as in Experiment II.

Rations

Each pig was self fed one of the mixed rations as shown in Table XIII. The chemical analysis of the ration fed appears in Table XIV. Kafir 44-14, purchased on the open market, was ground to different degrees of fineness and mixed with the other components. The rations differed only as to the preparation of the grain which was ground and fed as follows: ration I, whole; ration II, rolled; ration III, coarsely ground; and ration IV, finely ground. Solvent extracted soybean meal and alfalfa meal supplied the supplemental protein and vitamin A. B-complex vitamins and vitamin D were added to all rations in the amounts shown in Table VII. All rations were thought to be adequate with respect to mineral and vitamins. During the digestion trials, each ration contained 1.0 percent chromic oxide on a dry weight basis. The index material was mixed with a moistened portion of the ration and dried prior to mixing with the remainder of the ration. This was done to prevent the sifting of the chromic oxide due to its high specific gravity.

Table XIII

Percentage Composition of Rations Fed[1,2]
Experiment V - Spring 1955

Ration Number	I	II	III	IV
Kafir 44-14 (whole)	75.5	(rolled)	(coarsely ground)	(finely ground)
Soybean meal	15.9			
Alfalfa meal (dehydrated)	5.0			
Bone meal	2.0			
Salt	1.0	All rations identical to Ration I with the exception of the preparation of the grain portion.		
Aurofac[3]	.5			
Fortafeed[4]	.1			
Total	100.0			
Total protein	15.7			

[1]During the digestion trials all rations contained 1.0 percent Cr_2O_3 which was added to the complete ration on a dry weight basis.

[2]Vitamin D was supplied by a commercial vitamin supplement at a rate of 250 USP units of vitamin D_2 per pound of feed.

[3]Supplied .009 g. of auromycin and .009 mg. of B_{12} per pound of feed.

[4]Supplied 2.0 mg. riboflavin, 4.0 mg. pantothenic acid, 9.0 mg. niacin, and 90.0 mg. choline per pound of feed.

Table XIV

Chemical Composition of Ration Fed
Experiment V - Spring 1955

H_2O %	Ash %	Protein %	Fat %	Ca %	P %	Crude Fiber %	NFE %
10.85	4.46	15.68	3.24	.56	.57	2.26	63.51

Methods of Collecting Data

Two digestion trials were conducted at average weights of 63.6 and 132.6 pounds to determine comparative effect of methods of preparation on the rations during different stages of the feeding period. The method reported by Crampton *et al.*, (1952) was used. Two feces collections were made daily (11-12 a.m. and 5-6 p.m.) from the floor of the pens which were washed clean after each collection. Approximately 200 g. of feces were collected at each collection during the five-day period. All collections were kept under refrigeration in the presence of thymol crystals which were added as a preservative. At the end of the collection period, the feces were dried in a forced air oven at 105° C. After drying, the feces were ground to a very high degree of fineness and thoroughly mixed. From this total quantity of dried feces a sample of approximately 60 g. was taken as a sample for chromic oxide analysis. The colormetric method of analysis reported by Schurch *et al.*, (1950) was used and all analyses were made in duplicate. Digestion coefficients were calculated by the following formula: Digestion coefficient = $100\left(\frac{A-B}{A}\right)$ where A is the parts of dry matter per unit of index substance in the feed and B the parts of dry matter per unit of index substance in the feces.

Pigs were weighed individually every 14 days during the trial. All pigs were removed from the experiment after the second collection period was completed.

Feed consumption of each pig was based on the amount provided the pig during the experiment.

Results and Discussion

The results of Experiment V are summarized in Table XV. A statistical analysis of variance (Snedecor 1946) indicated no significant differences among the treatments with respect to daily gain or feed efficiency. In general, it is felt that the daily gains and feed efficiency presented in the data are not exactly representative of feed lot performance since the pigs were subjected to two digestion trials during the experiment. In each case, 1.0 percent chromic oxide was added to their ration. Any peculiar physiological effects due to the presence of chromic oxide have not been reported; however, it was noted that one pig used in the experiment consistently scoured immediately following the addition of the inert ingredient to the ration. From this it can only be assumed that chromic oxide may in some way have a physiological effect on the animals consuming the material.

Although not significantly different ($P < .12$) the average rate of gain produced by the finely ground grain (Lot IV) was from 10.1 to 17.6 percent higher than the rate of gain produced by grain prepared by the other methods.

Based on this experiment, the slightly faster rate of gain produced by the whole grain than by either the rolled or coarsely ground grains can only be attributed to the inherent differences existing in the pigs used. With respect to feed efficiency, although not significantly different, the amount of feed required per 100 pounds of gain was reduced as the grain was ground finer.

The first digestion trial conducted at an average weight of 63.6 pounds (Snedecor 1946) resulted in no significant differences among the digestion coefficients produced by the different treatments. The ration containing the whole grain (Lot I) produced an average dry matter digestion coefficient of 75.91 percent which was 3.77, 0.28, and 5.64 percent less than the average coefficients for the rations containing rolled, coarsely ground, and finely ground grain, respectively. The digestion coefficients for the rations containing the rolled (Lots II), coarsely ground (Lot III), and finely ground (Lot IV) grain were 79.68, 76.19, and 81.55, respectively. A correlation coefficient of .419 between daily feed intake and digestion coefficient indicates the differences in digestibility of the rations were not due to variation in feed consumption.

Table XV

Summary of Results
Experiment V - Spring 1955

Ration Number	I	II	III	IV
Preparation of grain	Whole	Rolled	Coarsely Ground	Finely Ground
Number of pigs in lot	4	4	4	4
Av. initial weight (lbs.)	42.5	40.5	40.7	41.0
Av. final weight (lbs.)	139.0	126.5	130.1	149.0
Av. total gain (lbs.)	96.5	86.0	89.4	108.0
Av. daily gain (lbs.)	1.27	1.17	1.17	1.42
Av. feed per 100 lbs. gain (lbs.)	345.4	314.3	317.7	300.6
Av. digestion coefficient (Av. pig weight 63.6 lbs.)	75.91	79.68	76.19	81.55
Av. digestion coefficient (Av. pig weight 132.6 lbs.)	64.01	77.56	81.72	85.43
Av. digestion coefficient (Av. of two trials)	69.96	78.62	78.95	83.54

In the second digestion trial conducted at an average weight of 132.6 pounds, the differences among the digestion coefficients for the different treatments were highly significant ($P < .01$). The multiple range test (Duncan 1955) indicated that the significant difference existed between the ration containing the whole grain (Lot I) and the other three rations (Lots II, III, and IV) which did not differ significantly among themselves. The correlation coefficient between daily feed intake and digestion coefficients was .216.

On the basis of this experiment it may be concluded, with respect to digestibility, that there is a definite advantage in grinding the sorghum grains to be used in swine fattening rations. This advantage proved significant only when the pigs were approximately half way through the feeding period. Although this same advantage was not, significantly, reflected in rate and efficiency of gain, the trend was increased rate and efficiency of gain as the grain was ground to decreasing particle size.

SUMMARY

Two experiments were conducted to test the effectiveness of various sources of supplemental protein for a grain sorghum, alfalfa meal, mineral ration to be fed to swine in dry lot. In Experiment I, a basal ration containing soybean meal alone as a source of supplemental protein produced a rate and efficiency of gain superior to that produced by tankage alone, tankage plus soybean meal, or soybean meal plus blood meal. A mixture of soybean meal and fish solubles improved rate of gain slightly over the basal ration, but the advantage was offset by an increased cost of the ration. The differences reported were slight and neither rate of gain nor efficiency of gain differed significantly in the final combination of the two trials making up the experiment. On the basis of this experiment it can be concluded that soybean meal is probably equal or superior to any supplement tested with respect to rate and economy of the gains produced.

Experiment II was conducted to test the value of low, free gossypol cottonseed meal as a complete or partial replacement for soybean meal as a source of protein in a grain sorghum, alfalfa meal, mineral ration for fattening swine in dry lot. Also tested was the effectiveness of supplementing the cottonseed meal with 0.2 percent DL-lysine. A basal ration containing soybean meal alone produced a significantly faster rate of gain than cottonseed meal alone or when supplemented with

0.2 percent L-lysine. The addition of lysine improved rate of gain slightly over the ration containing cottonseed meal alone, and the replacement of one half of the cottonseed meal with soybean meal resulted in an improved rate and efficiency of gain. These improvements, however, were not statistically significant. Feed efficiency, although not significantly different among the treatments, was in favor of the basal ration and the ration containing a mixture of soybean meal and cottonseed meal. On the basis of the experiment it is apparent that soybean meal contains a factor(s) in addition to its lysine content that make it superior to cottonseed meal as a protein supplement to soybean grain for fattening swine.

Two experiments were conducted to test the effectiveness of graded levels of alfalfa meal and a commercial vitamin A supplement in gelatin as sources of vitamin A activity to supplement a grain sorghum, blood meal, mineral ration for swine fed in dry lot. In Experiment III, 0.0, 0.5, 7.5, and 10.0 percent levels of alfalfa meal were fed. The treatments did not differ significantly with respect to rate or efficiency of gain. Only slight differences existed between the rate of gain produced by the different levels; however, efficiency of feed utilization was in favor of the ration containing no alfalfa meal. The practice of omitting a source of supplemental vitamin A cannot be recommended since one pig on the 0.0 percent level developed definite vitamin A deficiency symptoms near the end of the experiment. The increasing levels of alfalfa meal produced a linear increase with respect to plasma carotene and vitamin A as well as liver storage of vitamin A. Plasma carotene content did not differ significantly among treatments while plasma and liver vitamin A value differences were highly significant. In Experiment IV, 5.0, 7.5, and 10.0 percent levels of alfalfa meal and a commercial vitamin A supplement were fed. Rate and efficiency of gain did not differ significantly among the treatments. Among the levels of alfalfa meal, the feed required per 100 pounds of gain was in direct proportion to the alfalfa meal content of the ration. When fed at a rate to furnish 8000 USP units of vitamin A per pound of feed, the vitamin A supplement improved rate of gain slightly over the alfalfa meal rations. Feed efficiency was improved over the 7.5 and 10.0 percent levels of alfalfa meal but was inferior to the efficiency produced by the 0.5 percent level of alfalfa meal.

One experiment was conducted to test the value of different methods of preparing the sorghum grains to be used in swine rations. Two digestion trials were conducted by the chromic oxide method to determine the dry matter digestibility of rations containing whole, rolled, coarsely ground, and finely ground sorghum grain. Rate and efficiency of gain during the entire feeding period did not differ significantly. The trend, however, was definitely in favor of the finely ground grain. The digestion coefficients obtained during the first trial (average weight 63.6 pounds) did not differ significantly among treatments, but again the trend was in favor of the more finely ground grain. In the second digestion trial (average weight 132.6 pounds) the digestion coefficients differed significantly between the whole grain ration and the other methods of preparation used. The rations containing the rolled, coarsely ground, and finely ground grain did not differ significantly among themselves, but the trend was toward increased digestibility as the grain was ground to smaller particle size.

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